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Implementation Plan for a Multi-Year Biological Research Study at Ice Harbor Dam: Turbine Characterization and Acoustic Telemetry

February 2015

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract **DE-AC05-76RL01830**

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Acronyms and Abbreviations

AFEP	Anadromous Fish Evaluation Program
AHA	activity hazard analysis
ANOVA	analysis of variance
AR	autonomous receivers
AT	acoustic telemetry
ATLAS	Adjusted Tag-Life-Adjusted Survival
ATS	Advanced Telemetry Systems, Inc.
B&K	Brüel & Kjær
BOP	best operating point
BRZ	boa- restricted zone
BTT	balloon-tag technology
CENWW	Corps of Engineers Walla Walla
CF	compact flash
CDF	cumulative distribution function
CJP	complete joint penetration
CMV	commercial motor vehicle
COM	communication
COTR	Contracting Officer's Technical Representatives
CR	Columbia River
CRB	Columbia River Basin
CV	coefficient of variation
ERDC	Engineer Research and Development Center
ES&H	Environmental, Safety & Health
FCRPS	Federal Columbia River Power System
GPS	global positioning system
GTAW	gas tungsten arc welding
IACUC	Institutional Animal Care and Use Committee
IHR	Ice Harbor Dam
IP	Implementation Plan
JBS	juvenile bypass system
JFF	juvenile fish facility
JSATS	Juvenile Salmon Acoustic Telemetry System
LED	light-emitting diodes
LMN	Lower Monumental Dam
MDEV	mean deviance
MSDS	Material Safety Data Sheets

MSL	mean sea level
NMFS	National Marine Fisheries Service
PDT	Pacific Daylight Time
PFD	personal flotation device
PIT	passive integrated transponder
PM	Project Manager
PMP	Project Management Plan
PNNL	Pacific Northwest National Laboratory
POC	point of contact
PRI	pulse repetition interval
PSMFC	Pacific States Marine Fisheries Commission
QA/QC	quality assurance/quality control
RSW	removable spillway weir
SE	standard error
SF	Sensor Fish
SMP	Smolt Monitoring Program
SOP	Standard Operating Procedure
SR	Snake River
SRWG	Studies Review Work Group
SS	stainless steel
STS	submerged traveling screen
USACE	U.S. Army Corps of Engineers
USB	universal serial bus
USCG	U.S. Coast Guard
UV	ultraviolet
VAR	variance
VCP	virtual COM port
WA	Washington
WDFW	Washington Department of Fish and Wildlife

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1.0 Introduction

Pacific Northwest National Laboratory (PNNL) is preparing this Implementation Plan (IP) for conducting a multi-year biological research study at Ice Harbor Dam (IHR) to characterize the turbine environment and examine the implications on fish passage for the U.S. Army Corps of Engineers (USACE), Walla Walla District (CENWW).

1.1 Background

The turbines at existing hydroelectric facilities within the Columbia River basin (CRB) are aging and plans have begun to replace them with new designs to improve efficiency and fish passage. Ice Harbor Dam is the first installation within the Federal Columbia River Power System (FCRPS) to have turbines replaced, and so this will be the first opportunity to evaluate new designs and help to guide future turbine replacement designs at other facilities. The current schedule is to replace the turbine runners in Units #1–3 at IHR between 2014 and 2018.

The CENWW have two design options for the turbine replacements at IHR: (1) fixed blade style turbine and (2) adjustable blade (Kaplan) style turbine. Both of these turbines are currently being manufactured. Currently, Unit #2 is scheduled to be replaced with the new fixed blade design in 2016 and Unit #3 is scheduled to be replaced with the new adjustable blade design in 2017. To effectively evaluate the new designs, there is a need to collect baseline information about the environment of the current turbines, as well as the effects of this turbine environment on juvenile salmonids. Following installation, information on the environment of the new turbine designs and the effects on fish will be collected and compared to the original turbine and between the new turbine designs.

Evaluation of the new turbine runner designs will focus on three areas: (1) effects of passage through the turbine on survival of juvenile salmonids, (2) characterization of the turbine environment, (3) biological effects of the turbine environment on juvenile salmonids. The information collected in this study will allow the USACE to evaluate improvements to fish passage and may be used to steer future turbine runner design efforts for other facilities within the FCRPS.

1.2 Purposes, Objectives, and Approach

Our purpose herein is to provide a detailed plan to guide CENWW in performing future studies to characterize the turbine environment and estimate survival of turbine-passed fish at IHR on the Snake River (SR).

The primary objective of this study is to measure the relative improvement between the old and new turbines at IHR. Two new turbine types are being manufactured: (1) a fixed blade propeller and (2) adjustable blade (Kaplan) turbine runner similar to the existing runners. A secondary objective is to evaluate different characteristics of the turbines and compare the two designs. Finally, determining the absolute survival of fish through the new turbines, if possible, would be advantageous.

1.3 Schedule

This study will occur over 5 years at IHR. During these years, data will be collected on the baseline and new turbine environments of Units #1 – 3. The testing schedule for the study at IHR is depicted in the following timeline (Table 1.1). Preliminary baseline testing will begin in 2014 and full-scale baseline testing is expected to begin in 2017.

Table 1.1. Schedule for testing Turbine Units #1 – 3 at IHR. Tests will include acoustic telemetry (AT), turbine characterization using Sensor Fish (SF), and bio-testing using balloon-tag technology (BTT) and SF as noted below.

Year	Unit #1	Unit #2	Unit #3
2014	Baseline (SF[a])		
2015	Baseline (SF[b])		
2016 or FYXX		Out of service	
2017 or FYXX+1	Baseline (BTT and SF[c,d])	New fixed blade test (BTT, SF, and AT)	Out of service
2018 or FYXX+2	Out of service		New Kaplan runner test (BTT, SF, and AT)

(a) Baseline (SF only) testing can occur in either Unit #3 or #1, with Unit #3 as the preference.
(b) Continuations from FY14. FY15 will likely be the year with the bulk of data collection with SF due to approval process for the release pipe design and other logistics.
(c) For correlation/characterization of BTT.
(d) There is a potential baseline study using AT. To be determined at a later date.

The milestone schedules for AT, turbine characterization, and bio-testing studies at IHR are depicted in the following timelines (Table 1.2−1.4).

Table 1.2. Schedule of major activities and milestones related to conducting an AT turbine survival test at IHR. In this table FYXX represents the given year that an AT study will be conducted and is not referencing a specific calendar year.

Milestone Activity	Activity Dates		FYXX												FYXX+1					
	Start	Finish	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Preparation	10/1/XX	3/31/XX	■	■	■	■	■	■												
Acceptance testing - autonomous receivers	2/1/XX	3/31/XX					■	■												
Acceptance testing - cabled receivers	2/1/XX	3/31/XX					■	■												

Table 1.2. (contd)

Milestone Activity	Activity Dates: Start	Finish	FYXX: Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	FYXX+1: Oct	Nov	Dec	Jan	Feb	Mar
Acceptance testing - transmitters	2/1/XX	3/31/XX					■	■												
Fish tagging (yearling Chinook)	4/22/XX	5/31/XX							■	■										
Fish tagging (subyearling Chinook)	6/1/XX	7/15/XX									■	■								
Data collection	4/22/XX	8/15/XX							■	■	■	■	■							
Data management	4/22/XX	3/31/XX +1							■	■	■	■	■	■	■	■	■	■	■	■
Data analysis	5/1/XX	3/31/XX +1								■	■	■	■	■	■	■	■	■	■	■
Bi-weekly progress reports	4/19/XX	8/30/XX							■	■	■	■	■							
Draft report due		3/31/XX +1																		■

Table 1.3. Schedule of major activities and milestones related to conducting a turbine characterization test using SF at IHR. In this table FYXX represents the given year that a study to characterize the turbine environment will be conducted and is not referencing a specific calendar year.

Milestone Activity	Activity Dates: Start	Finish	FYXX: June	July	Aug	Sept	FYXX+1: Oct	Nov	Dec	Jan	Feb	Mar	Apr	June
Preparation	6/1/XX	8/31/XX	■	■	■									
Injection system deployment	8/1/XX	9/30/XX			■	■								
Acceptance testing - SF	8/1/XX	8/31/XX			■									
Data collection	10/1/XX+1	11/30/XX+1					■	■						
Data management	10/1/XX+1	6/30/XX+1					■	■	■	■	■	■	■	■
Data analysis	10/1/XX+1	6/30/XX+1					■	■	■	■	■	■	■	■
Preliminary report		1/31/XX+1								■				
Draft report due		6/30/XX+1												■

Table 1.4. Schedule of major activities and milestones related to conducting bio-testing using BTT and SF at IHR. In this table FYXX represents the given year that bio-testing will be conducted and is not referencing a specific calendar year.

Milestone Activity	Activity Dates		FYXX											
	Start	Finish	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Preparation	12/1/XX	2/28/XX												
Injection system deployment	2/1/XX	2/28/XX												
Acceptance testing – radio receivers	1/1/XX	2/28/XX												
Acceptance testing – radio transmitters	1/1/XX	2/28/XX												
Data collection	3/1/XX	3/31/XX												
Data management	3/1/XX	9/30/XX												
Data analysis	3/1/XX	9/30/XX												
Preliminary report		5/31/XX												
Draft report due		9/30/XX												

1.4 Implementation Plan Contents and Organization

The ensuing sections of this IP describe the experimental design (Section 2.0), and the activities associated with study implementation (Section 3.0), including preparation, data collection, data management and analysis, quality assurance and quality control (QA/QC), and reporting for AT survival, turbine characterization, and bio-testing studies. Project management is addressed in Section 4.0. Supplemental information is provided in Appendix A through Appendix H, as follows:

Appendix A – Environmental Health & Safety Plan
Appendix B – Equipment
Appendix C – Hydraulic Extent Detail
Appendix D – Maps and Coordinates of Autonomous Receiver Arrays
Appendix E – Fish Collection, Tagging, and Release Schedule
Appendix F – Acoustic Telemetry Data Management
Appendix G – Sensor Fish Injection System
Appendix H – Ice Harbor Dam Boat Restricted Zone Policy.

2.0 Experimental Design

2.1 Acoustic Telemetry Survival Study

A paired release-recapture design will be used to estimate turbine passage survival of acoustic-tagged fish (Figure 2.1). Treatment fish will be released into the turbine (R_1) and control fish will be released concurrently into the tailrace (R_2) just downstream of the turbine being evaluated and approximately 200 ft downstream of IHR through the bypass pipe (R_3). Treatment fish will be used to estimate turbine passage survival and survival through the tailwaters to the first downstream detection array. The control fish will be used to estimate survival from the tailrace through the tailwaters to the first downstream detection array. Turbine passage survival will then be estimated by the quotient:

$$\hat{S}_{\text{Tur}} = \frac{\hat{S}_1}{\hat{S}_2}$$

Due to the anticipated short travel times of fish in this study, no tag-life study will be performed to provide tag-life-adjusted survival estimates. The variance of $\hat{S}_{\text{Tur}}$ is estimated by:

$$\widehat{\text{Var}}(\hat{S}_{\text{Tur}}) = \hat{S}_{\text{Tur}}^2[\text{CV}(\hat{S}_1)^2 + \text{CV}(\hat{S}_2)^2]$$

where CV represents the coefficients of variation.

Releases of ~32 dead tagged fish, per stock, will be performed to assure the first detection array is sufficiently far enough downstream to avoid detections of dead-tagged fish (termed false-positive detections). Plots of the downstream arrival distributions will be used to assess mixing of the control and treatment fish.

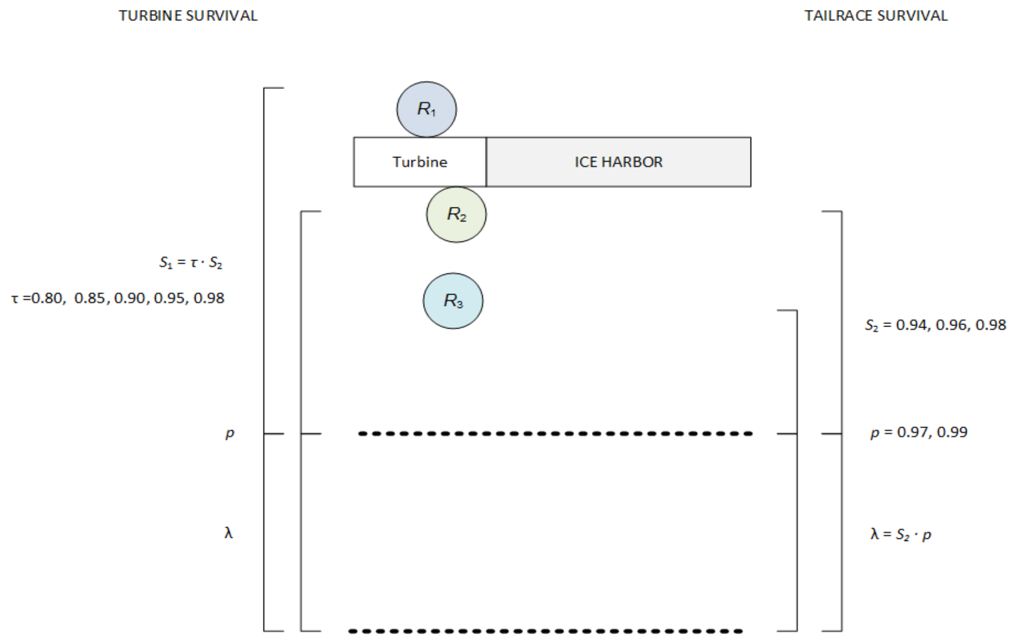


Figure 2.1. Schematic of paired-release designs used to estimate turbine passage survival (i.e., $\boldsymbol{R_1}$ vs. $\boldsymbol{R_2}$) and tailrace survival ($\boldsymbol{R_2}$ vs. $\boldsymbol{R_3}$) using JSATS-tagged fish. Parameter values used in sample size calculations noted. Survival estimates based on the paired-release calculated as $\boldsymbol{\hat{S}_1/\hat{S}_2}$ for either pairing.

2.1.1 Sample Size Calculations

Sample size calculations focused on the release sizes for R_1, R_2, and R_3 (Table 2.1) necessary to obtain an SE ≤0.015. In performing the sample size calculations, the minimum detection configuration of two downstream arrays (a group of autonomous receivers; ARs) was assumed as depicted in Figure 2.1. Calculations were based on estimates of the reach survival, turbine survival, and detection probabilities likely to be encountered during a study (Table 2.1). These estimates were based on historical values observed from other acoustic-tag studies either conducted at IHR or at other dams in the lower Snake and Columbia rivers (i.e., Little Goose Dam, Lower Monumental Dam [LMN], and McNary Dam).

Table 2.1. Release sizes ($\boldsymbol{R_1}$ = $\boldsymbol{R_2}$ =$\boldsymbol{R_3}$) required to obtain an estimated SE ≤0.015 for various detection probabilities ($\boldsymbol{p_1}$ =$\boldsymbol{p_2}$), reach survivals ($S_2 = S_3$), and turbine passage survivals (τ) in the IHR AT paired-release study.

S	*p* =	0.97					0.99				
	τ =	0.8	0.85	0.9	0.95	0.98	0.8	0.85	0.9	0.95	0.98
0.94		1140	1040	910	770	670	1130	1020	900	750	650
0.96		1000	880	740	580	470	990	870	730	560	460
0.98		860	730	570	400	280	850	720	560	390	270

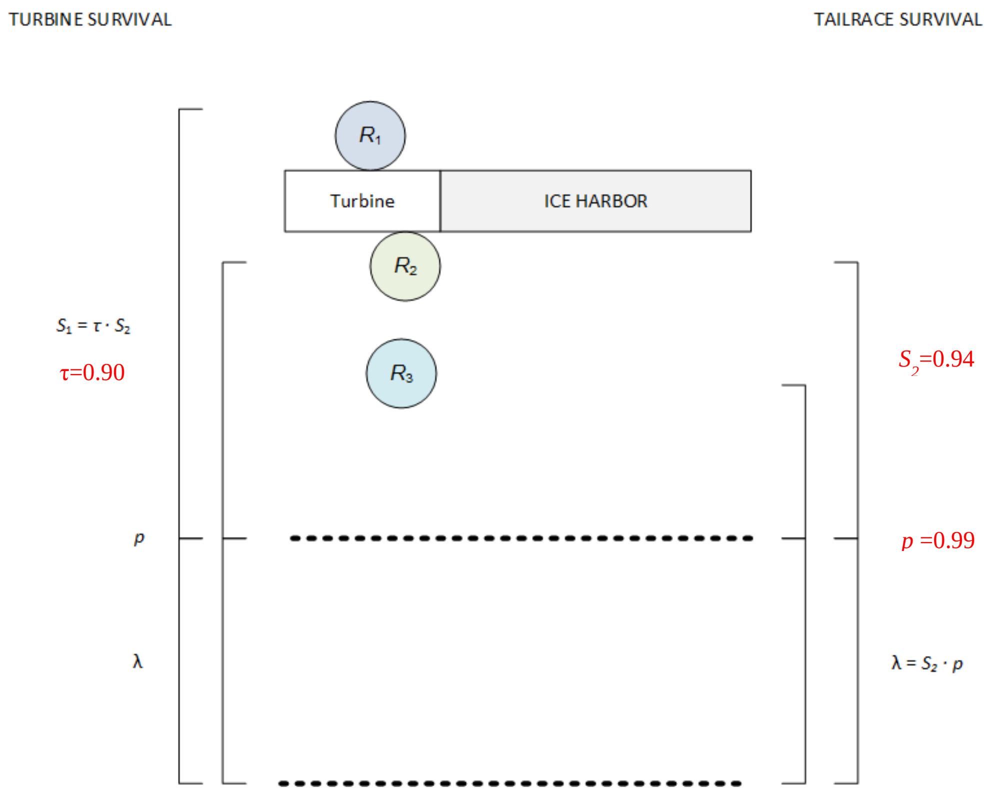


Figure 2.2. Schematic of paired-release designs used to estimate turbine passage survival (i.e., R_1 vs. R_2) and tailrace survival (R_2 vs. R_3) using JSATS tagged yearling Chinook salmon. Parameter values used in sample size calculations are noted. Survival estimates based on the paired-release were calculated as $\hat{S}_1/\hat{S}_2$ for either pairing.

For IHR, the survival and detection parameter values used in the sample size calculations are summarized in Figure 2.2 and Figure 2.3 for yearling and subyearling Chinook salmon, respectively.

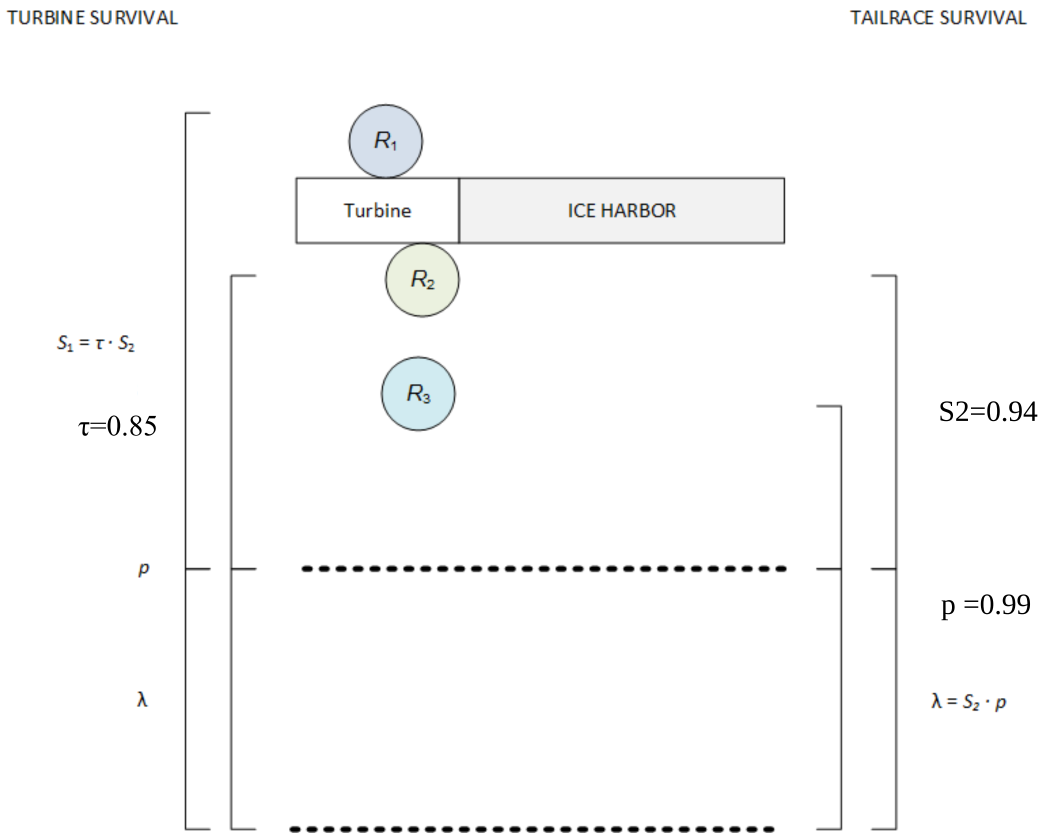


Figure 2.3. Schematic of paired-release designs used to estimate turbine passage survival (i.e., $\boldsymbol{R_1}$ vs. $\boldsymbol{R_2}$) and tailrace survival ($\boldsymbol{R_2}$ vs. $\boldsymbol{R_3}$) using JSATS tagged subyearling Chinook salmon. Parameter values used in sample size calculations are noted. Survival estimates based on the paired-release were calculated as $\boldsymbol{\hat{S}_1/\hat{S}_2}$ for either pairing.

For yearling Chinook salmon testing at IHR, sample sizes of 900 fish at each release location (R_1, R_2, R_3) is recommended (Table 2.2). For subyearling Chinook salmon testing, sample sizes of 1,020 fish at each release location is recommended (Table 2.2). Therefore, a total of 2,700 (= 900 + 900 + 900) yearling Chinook salmon and 3,060 (= 1,020 + 1,020 + 1,020) subyearling Chinook salmon are required for a single year of testing.

Table 2.2. Calculated sample sizes for releases ($\boldsymbol{R_1}$, $\boldsymbol{R_2}$, $\boldsymbol{R_3}$) based on historical detection probabilities and reach and turbine survival for the evaluation of new turbine designs at IHR to achieve SE ≤0.015 by fish stock.

Stock	Release		Recommended sample size
Yearling Chinook salmon	R_1		900
	R_2		900
	R_3		900
		Total	*2,700*

Table 2.2. (contd)

Stock	Release	Recommended sample size
Subyearling Chinook salmon	R_1	1,020
	R_2	1,020
	R_3	1,020
	Total	*3,060*
	Two stocks total	*5,760*

2.2 Characterization of the Turbine Passage Environment

An experimental design for the characterization of the turbine environment and the release design at each turbine unit will be generated prior to the start of field work each year, taking into account the multiple objectives of the evaluation (e.g., turbine evaluation, Biological Performance Assessment model evaluation). The requirements for testing are as follows:

1) Release location
    a. All releases will occur in Slot B for existing units #1 and #3.
2) Testing elevations (Figure 2.4)
    a. 314.5 ft (Blade tip)
    b. 327 ft (Mid-blade)
    c. 337 ft (Blade hub)
3) Time period of testing (all testing periods will occur when screens are in place)
    a. September to November (no spill)
    b. April to August (with spill)
4) Turbine operations
    a. Baseline testing/New adjustable blade turbine
        i. Lower limit
        ii. Upper/generator limit
        iii. Peak
        iv. Best operating point (BOP)/design limit for fish passage
    b. New fixed blade turbine
        i. Lower limit
        ii. Upper/generator limit
        iii. Peak

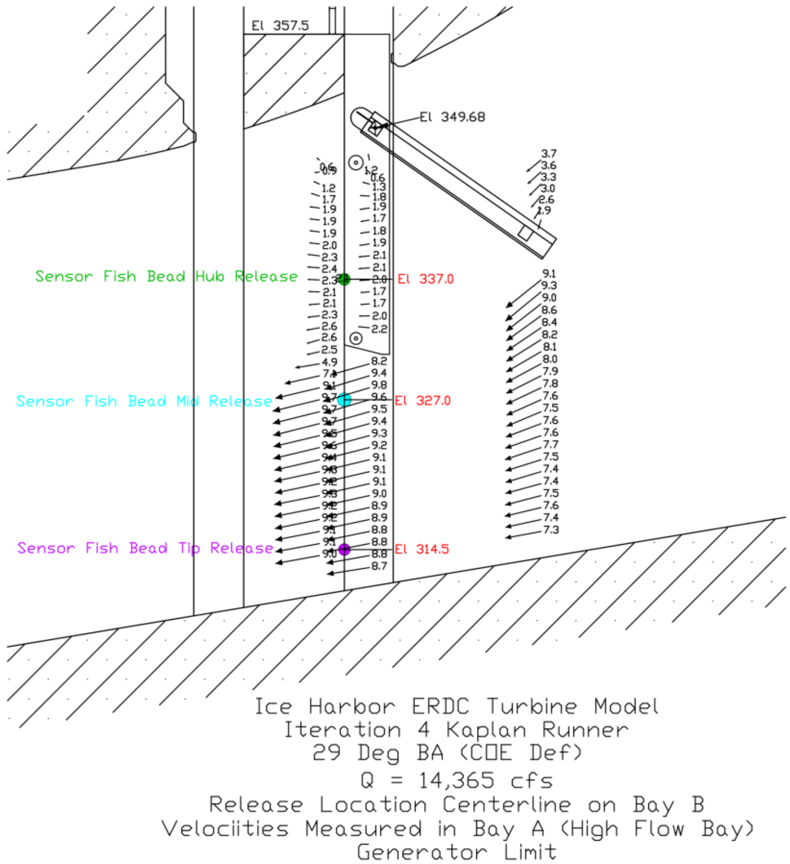


Figure 2.4. SF release locations by elevations and water velocities in powerhouse unit, Slot B.

2.2.1 Sample Size Calculations

Sample size calculations focused on power calculations to detect differences in nadir pressure distributions (i.e., cumulative distribution function [cdf]) based on the Kolmogorov-Smirnov test using historical nadir pressure distributions at IHR. To detect a difference of 1.0 psi between sample distributions, using $\alpha = 0.05$ and a one-tailed test, a total of 200 SF should be released per operating condition to achieve statistical power approaching 1.0 (Figure 2.5). Therefore approximately 800 SF releases are needed (= 200 SF per operating condition x 4 operating conditions). This sample size is divided evenly among release elevations. An example of a possible test block is shown in Table 2.3.

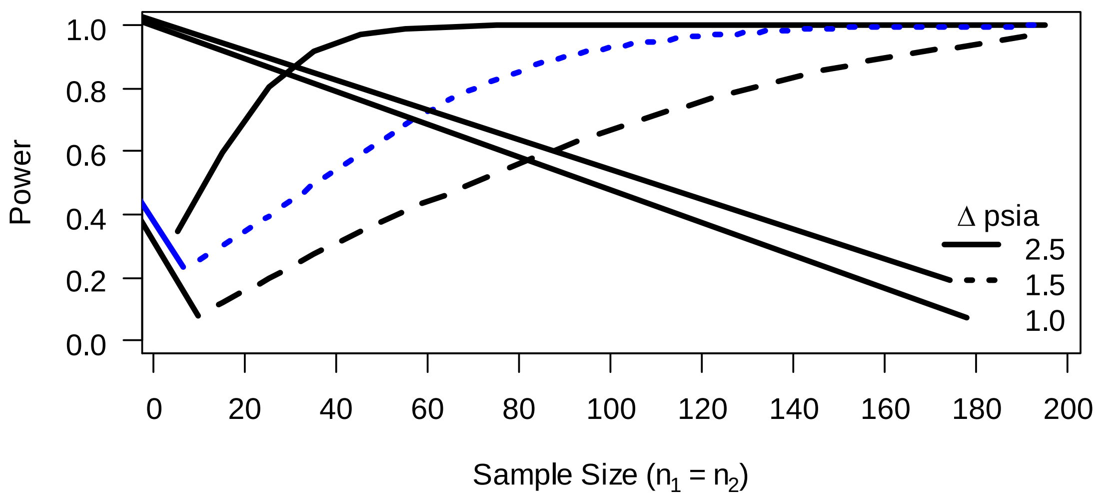


Figure 2.5. Statistical power (1-β) to detect a difference in nadir distributions between old- and new-generation turbines at $\alpha = 0.05$, one-tailed, for various sample sizes using a Kolmogorov-Smirnov test. Simulations were based on a historical nadir distribution from IHR and a 2.5-, 1.5-, or 1.0-psi difference.

Table 2.3. Possible randomized tests block and sample sizes for SF releases through a turbine unit at IHR.

Day	Operating level	Turbine slot	Depth	Sample size
1	Lower Generation Limit	B	314.5	67
2	Lower Generation Limit	B	327.0	67
3	Lower Generation Limit	B	337.0	67
4	Upper Generation Limit	B	314.5	67
5	Upper Generation Limit	B	327.0	67
6	Upper Generation Limit	B	337.0	67
7	Peak Generation	B	314.5	67
8	Peak Generation	B	327.0	67
9	Peak Generation	B	337.0	67
10	BOP/design	B	314.5	67
11	BOP/design	B	327.0	67
12	BOP/design	B	337.0	67
				804

2.3 Bio-Testing

A paired release-recapture model will be used to measure direct survival of balloon-tagged fish that pass through the turbine environment, alternating in-turbine and control releases. A two-factor factorial treatment design will be used. The two factors are intake slot (A, B, and C) and operating level (lower generator limit, upper generator limit, and peak). An optional BOP operating level (design limit for fish passage) may also be included for existing and new Kaplan designs. Resulting factorial designs will result in either 9 or 12 treatment combinations. The BTT releases will be performed in a randomized block design with the 9 or 12 treatment combinations applied randomly within a block (Table 2.4). Testing in the A and B intakes will be at 325.7 ft elevation above mean sea level (msl) and testing in the C intake will be at 327.5 ft msl. An example of a possible test block is shown in Table 2.4. In order to correlate the biological effects and turbine environment that fish are exposed to, BTT releases will be coupled with SF releases.

Table 2.4. A possible test block for balloon-tag fish and SF releases through a turbine unit at IHR.

Day	Operating Level	Turbine Slot	Depth (ft msl)
1	Upper Generation Limit	C	327.5
2	Lower Generation Limit	C	327.5
3	Peak Generation	A	325.7
4	Peak Generation	B	325.7
5	Lower Generation Limit	B	325.7
6	Upper Generation Limit	B	325.7
7	Lower Generation Limit	A	325.7
8	Upper Generation Limit	A	325.7
9	Peak Generation	C	327.5

2.3.1 Basic Balloon-Tag Release Recapture Model

The estimates of turbine passage survival are based on a paired release of treatment and control fish through and below the turbine, respectively. The control fish are used to account for any handling effects and incomplete recovery rates upon recapture. The treatment fish will experience the additional effect of turbine passage. The individual fish are characterized as alive, dead, or not recovered upon attempts to recapture the fish in the tailrace of the dam (Figure 2.5).

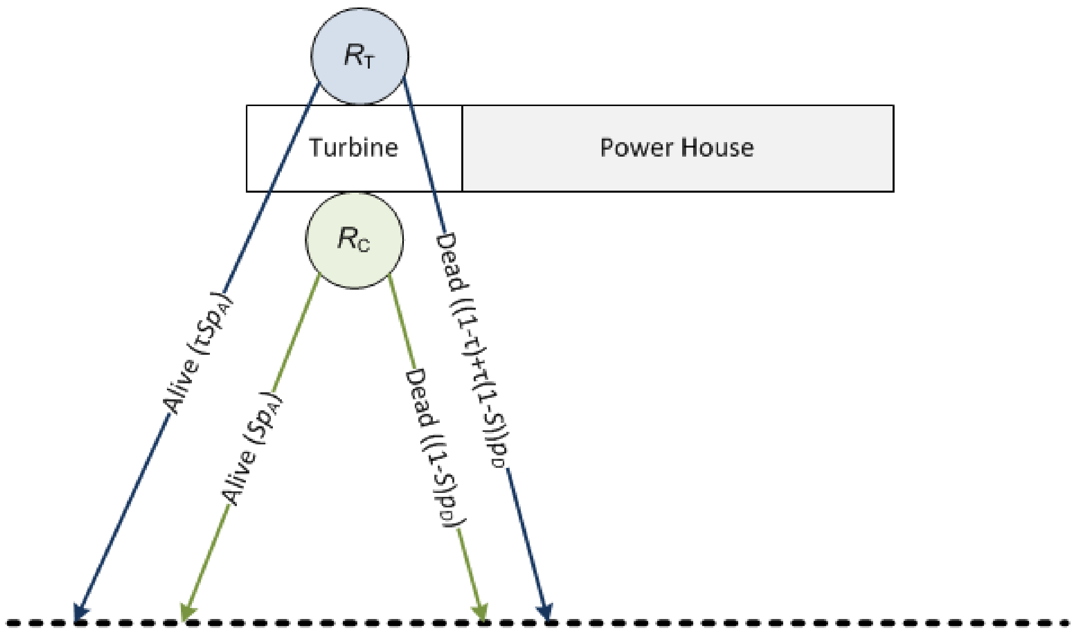


Figure 2.6. Schematic of a balloon-tag study with turbine survival ($\boldsymbol{\tau}$), tailrace survival ($\boldsymbol{S}$), and detection probabilities for alive ($\boldsymbol{p_A}$) and dead ($\boldsymbol{p_B}$) fish recoveries.

For the simple case of one control and one treatment release, the data from the release-recapture study are as follows:

R_C = total number of control fish released,

a_C = number of control fish recovered alive,

d_C = number of control fish recovered dead,

R_T = total number of treatment fish released,

a_T = number of treatment fish recovered alive,

d_T = number of treatment fish recovered dead.

The release-recapture study can estimate four parameters associated with turbine passage; these are:

S = probability a fish survives from below the turbine to recovery in the tailrace,

τ = turbine passage survival,

p_D = probability a dead fish is recovered,

p_A = probability a live fish is recovered.

Maximum likelihood estimation is used to estimate parameters based on the joint likelihood model:

$L(S, \tau, p_D, p_A | R_C, R_T, a_C, a_D, d_C, d_T)$ =

$$\binom{R_C}{a_C, d_C}(Sp_A)^{a_C}\left((1-S)p_D\right)^{d_C}(1-Sp_A-(1-S)p_D)^{R_C-a_C-d_C}$$

$$\cdot\binom{R_T}{a_T, d_T}(S\tau p_A)^{a_T}\left((1-S\tau)p_D\right)^{d_T}(1-S\tau p_A-(1-S\tau)p_D)^{R_T-a_T-d_T}$$

The maximum likelihood estimates for the parameters are:

$$\hat{\tau}=\frac{a_T R_C}{R_T a_C}$$

$$\hat{S}=\frac{R_T d_C a_C - R_C d_T a_C}{R_C d_C a_T - R_C d_T a_c}$$

$$\hat{p}_A=\frac{d_C a_T - d_T a_C}{R_T d_C - R_c d_T}$$

$$\hat{p}_D=\frac{d_C a_T - d_T a_C}{R_C a_T - R_T a_C}.$$

The variance (VAR) and standard error (SE) of the estimated turbine passage mortality $(1-\tau)$ or survival $(\hat{\tau})$ are:

$$\mathrm{Var}(1-\hat{\tau})=\mathrm{Var}(\hat{\tau})=\frac{\tau}{Sp_A}\left[\frac{(1-S\tau p_A)}{R_T}+\frac{(1-Sp_A)\tau}{R_C}\right]$$

$$\mathrm{SE}(1-\hat{\tau})=\mathrm{SE}(\hat{\tau})=\sqrt{\mathrm{Var}(1-\hat{\tau})}.$$

The likelihood model is based on the following assumptions:

1. The fate of each fish is independent.
2. The control and treatment fish come from the same population of inference.
3. Control and treatment fish share the same tailrace survival probability S.
4. All alive fish have the same probability, p_A , of recapture.
5. All dead fish have the same probability, p_D, of recapture.
6. Turbine passage survival (τ) and tailrace survival (S) to the recovery point are conditionally independent.

2.3.2 Release-Recapture Model

The study consists of one control and 9 or 12 treatment conditions replicated B times in a randomized block design (Table 2.5). Consequently, the data structure and statistical model are more complex. The following terms are defined:

n_{ij} = number of smolts released in the test of the iTh turbine condition ($i = 1, \cdots, 9$ or 12) for the jth test block ($j = 1, \cdots, B$);

a_{ij} = number of smolts recovered alive in the test of the ith turbine condition ($i = 1, \cdots, 9$ or 12) for the jth test block ($j = 1, \cdots, B$);

d_{ij} = number of smolts recovered dead in the test of the ith turbine condition ($i = 1, \cdots, 9$ or 12) for the jth test block ($j = 1, \cdots, B$);

τ_{ij} = probability a smolt survives the passage through the ith turbine condition ($i = 1, \cdots, 9$ or 12) for the jth test block ($j = 1, \cdots, B$);

S_j = probability a smolt survives the common tailrace area prior to the recovery for the jth test block ($j = 1, \cdots, B$);

p_{Aj} = probability of recapturing a live smolt for the jth test block ($j = 1, \cdots, B$);

p_{Dj} = probability of recapturing a dead smolt for the jth test block ($j = 1, \cdots, B$);

n_{Cj} = number of control smolts released for the jth test block ($j = 1, \cdots, B$);

a_{Cj} = number of control smolts recovered alive for the jth test block ($j = 1, \cdots, B$);

d_{Cj} = number of control smolts recovered dead for the jth test block ($j = 1, \cdots, B$).

The recoveries from the control and treatment releases can then be modeled by a joint likelihood composed of $B + 9B$(or $B + 12B$) different independent trinomial distributions, where

$$L\left(\tau_{ij}, S_j, p_{Aj}, p_{Dj} \middle| a_{Cj}, d_{Cj}, n_{Cj}, a_{ij}, d_{ij}, n_{ij}\right) =$$

$$\prod_{j=1}^{B} \binom{n_{Cj}}{a_{Cj}, d_{Cj}} \left(S_j p_{Aj}\right)^{a_{Cj}} \left(\left(1 - S_j\right) p_{Dj}\right)^{d_{Cj}} \left(1 - S_j p_{Aj} - \left(1 - S_j\right) p_{Dj}\right)^{n_{Cj} - a_{Cj} - d_{Cj}}$$

$$\cdot \prod_{j=1}^{B} \prod_{i=1}^{18} \binom{n_{ij}}{a_{ij}, d_{ij}} \left(\tau_{ij} S_j p_{Aj}\right)^{a_{ij}} \left(\left(1 - \tau_{ij} S_j\right) p_{Dj}\right)^{d_{ij}} \left(1 - \tau_{ij} S_j p_{Aj} - \left(1 - \tau_{ij} S_j\right) p_{Dj}\right)^{n_{ij} - a_{ij} - d_{ij}}.$$

Iterative numerical techniques based on the Newton-Raphson method will be used to estimate the parameters and the variance-covariance matrix. Special cases of the generic full model will also be analyzed using constraints on the treatment survival parameters (i.e., $\tau_{ij}, i = 1, \cdots, 9; j = 1, \cdots, B$) in constructing the analysis of deviance table (ANODEV).

2.3.3 Analysis of Deviance

Using the likelihood model, ANODEV will be used to test for differences in turbine passage survival under alternative treatment conditions. The ANODEV is analogous to analysis of variance (ANOVA), in the case in which the data are not expected to be normally distributed. The ANODEV will be used to test for the main effects of turbine type, operating level, release elevation and intake slot (Table 2.5).

Table 2.5. Proposed ANODEV tables for the randomized block, 3 x 3, factorial treatment design, balloon-tag study at IHR.

	Source	DF	DEV
	$\text{Total}_{\text{Cor}}$	$9B-1$	$2(M_F - M_M)$
	Block	$B-1$	$2(M_F - M_M - M_B)$
	Treatment	8	
(Main Effects)	Power Level	2	$2(M_{B\cdot P} - M_B)$
	Slots	2	$2(M_{B\cdot S} - M_B)$
(2-Way Interactions)	Power Level × Slots	4	$2(M_{B\cdot PS} - M_{B\cdot P} - M_{B\cdot S} + M_B)$
	Error	$8B-8$	e$2(M_F - M_B - M_{B\cdot PS})$

Numerous special cases of likelihood will be constructed and compared in developing the ANODEV table. Some of the specific models include the following:

Model M_F: Full model – the model has unique estimates of turbine passage survival, one for each treatment combination in each test block.

Model M_M: Grand mean model – model with one common parameter for turbine passage survival.

Model M_B: Block model – this model describes turbine passage survival adjusted for grand mean and B-1 multiplicative block effects.

Model $M_{B\cdot P}$: Operational level main effects, given block model – this model has 3 unique power effects only (i.e., $P_1, \cdots, P_3$) which are then modified by $(B-1)$ multiplicative block effects $(B_2, \cdots, B_B)$.

Model $M_{B\cdot S}$: Slot main effects, given block model – this model has 3 unique slot effects only (L_1, L_2, L_3) which are then modified by $(B-1)$ multiplicative block effects $(B_2, \cdots, B_B)$.

Model $M_{B\cdot PS}$: Power level x slot interactions, given block model – this model has 4^k turbine x depth parameters only (i.e., $DS_{11}, DS_{12}, DS_{21}, DS_{22}$) which are modified by $(B-1)$ multiplicative block effects $(B_2, \cdots, B_B)$.

The values of the mean deviance (MDEV) in the ANODEV will be calculated from the DEV divided by their respective degrees of freedom. F-tests of main effects or interactions will be based on the ratio of a MDEV for the effect divided by the error mean deviance ($MDEV_{Err}$).

2.3.4 Comparison of Turbine Performance

The primary test of concern is a comparison of turbine passage survival between new and existing turbines. The ANODEV was used to test the main effect of turbine type—in particular, the hypotheses

$$H_o: \tau_{New} \geq \tau_{Old}$$

versus

$$H_a: \tau_{New} < \tau_{Old}.$$

The ANODEV will be a modification of Table 2.5, with the effect of turbine added and block effects removed—In other words, a test to see if the new generation turbine has passage survival (τ_{New}) no worse than the existing turbines (τ_{Old}).

However, the main effects in the ANODEV may be misleading if there are significant interactions. In particular, the main effect of the turbine type may be misinterpreted if there are significant turbine-by-other-factor interactions. It is for this reason the ANODEV will also be used to test for interactions between treatment factors. The statistical tests were used to identify those factors that had a significant effect on turbine passage survival. The results of the ANODEV will be used to identify the most parsimonious description for the factors affecting turbine passage survival.

2.3.5 Sample Size Calculations

Sample size calculations focused on a paired-release design ($R_C = R_T$) necessary to obtain an SE ≤0.015. Calculations were based on estimates of turbine passage survival, survival rate of control fish, and the probability of recovering alive and dead fish (Table 2.6). These estimates should be based on either historical values observed from other balloon-tag studies conducted at IHR or at other dams in the lower Snake and Columbia rivers. In the case of a multiple-release design, these sample sizes pertain to each treatment condition investigated. A common control sample size of R_C pooled over all treatment trials can be used. The recommended sample size per treatment will be defined prior to testing.

Table 2.6. Release sizes ($\boldsymbol{R_C} = \boldsymbol{R_T}$) required to obtain an estimated SE on treatment effect of 0.015 for various probabilities of recovering alive and dead fish ($\boldsymbol{p_A} = \boldsymbol{p_D}$), control group survival ($\boldsymbol{S_C}$), and estimates of turbine passage survival (τ) in the IHR BTT study.

S_C	$p_A = p_D =$	0.97				0.99			
	τ =	0.85	0.9	0.95	0.98	0.85	0.9	0.95	0.98
0.95		1094	986	859	774	989	864	718	612
0.97		947	826	686	592	839	700	541	435
0.99		806	672	519	418	695	544	371	257

3.0 Study Implementation

Implementation of the study to evaluate the turbine and tailrace environment at IHR will consist of five main phases: Preparation, Data Collection, Data Management and Analysis, Quality Assurance/Quality Control, and Reporting. It also will provide details related to the development and implementation of environmental safety and health (ES&H) plans to mitigate the potentially dangerous conditions involved in work at dams, in reservoirs, and in rivers (Appendix A). Each phase is contingent on data from its predecessor, although activities for data collection, management, analysis, and reporting will necessarily have some overlap in time to expedite reporting.

3.1 Acoustic Telemetry Study

3.1.1 Preparation

The main categories of preparation are equipment, procurements, personnel and logistics, training, and deployment. Preparation will be complete when all equipment, hardware, and software have been finalized, all procurements have been received and accepted, all personnel have been trained and logistics completed, all test fish collection and tagging procedures are in place, and all systems and arrays have been deployed, tested, and certified as being ready to collect data. The preparation phase must be finished by one week prior to the start of fish collection in the year of study.

3.1.1.1 Equipment

The JSATS will be used to investigate juvenile salmon survival rates for the CENWW biological research study at IHR and will consist of transmitters (tags), cabled receiver arrays deployed on the tailrace side of the dam, and autonomous receiver arrays. To describe the system in brief, a signal emitted by a transmitter implanted in a test fish is received by an underwater hydrophone (attached to the receiver) and sent to a digital signal processor where the wave form is detected, decoded, and the output written to a storage device. A comprehensive list of equipment needed for the AT portion of this study can be found in Appendix B, Table B.1. Specific requirements for transmitters, cabled and ARs, and the fish injection system are listed below.

Transmitters

The downsized JSATS transmitter model is being planned to be used in this study. This transmitter has been developed by the USACE and PNNL. The downsized transmitter will meet or exceed the tag size and functional requirements provided by the USACE for performance standard evaluations. These specifications are listed in Table 3.1. In the event that the downsized transmitter is not available for use, the Advanced Telemetry Systems, Inc. (ATS) third-generation acoustic transmitter containing a single 337 battery will be used; the surgical methods and training criteria will follow methods outlined in McMichael et al. 2012.

Table 3.1. Minimum manufacturing specifications of JSATS transmitters to be used for the evaluation of new turbine designs at IHR.

Parameter	Specification
Size	12.00 mm length × 6.00 mm width × 4.10 mm thickness and a maximum volume of 300 mm^3
Weight	Dry weight not to exceed 430 mg
Surface roughness	The tag exterior shall be smooth and devoid of sharp edges or protrusions.
Coating	Tags shall be uniformly coated with parylene-C, or equivalent, to a minimum thickness of 25 microns
Biocompatibility	Biologically inert coating
Transmitter frequency	416.7 ± 0.5% Hz
Transmitter power	Minimum source level of +153 dB (re: 1µPa @ 1 m)
Transmitter beam pattern	Uniform beam pattern -3 dB minimum
Message transmit interval	Factory configurable to 2, 3, 5, 7, and 10 seconds (± 5%)
Minimum run time	3-s version: 20 days; 5-s version: 30 days; 10-s version: 55 days
Message encoding	31 bits, BPSK (binary phase shift keying) with format as follows: 7-bit barker code (0x72); 16-bit tag identification code (0x0000 - 0xFFFF); 8-bit cyclic redundancy check (CRC), (0xFF)
Message length	744 µs
Number of possible tag identification (ID) codes	65,536
Shelf life	Tags shall retain >85% of battery capacity for 12 months after manufacture when stored at room temperature in an inactivated state.
On/Off switch	Yes; no wires will be accepted
Transmitter label	Discernable 4-character code representing the 16-bit tag ID code (0xFFFF)

Downsized acoustics tags to be used in this study will have a median size of 15.1 mm long, 3.3 mm diameter, weigh 218 mg in air, and have a volume of 1 mm^3 (Figure 3.1). The tags will have a nominal transmission rate sufficient to accurately track fish behavior in the tailrace of the dam. Each pulse from a JSATS tag contains a complex phase-encoded signal that uniquely identifies the transmitting tag without a purposeful variation in pulse duration. Each tag will be implanted into a fish within 96 hours of being activated. Nominal tag-life will be >100 days for 3-s tags (Figure 3.2).

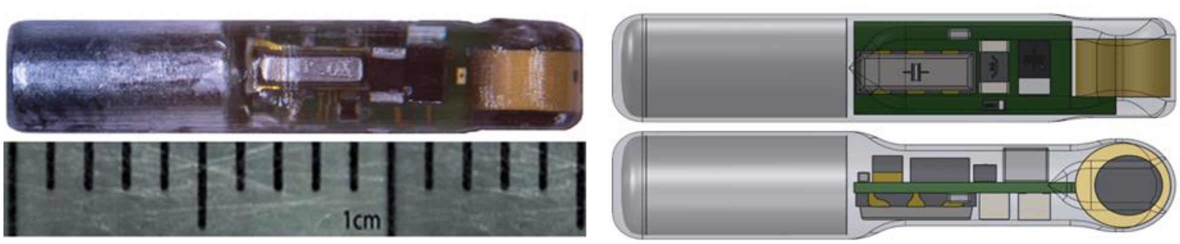


Figure 3.1. Photograph and drawing of the downsized JSATS transmitter that will be used to evaluate the new turbine runner designs at IHR.

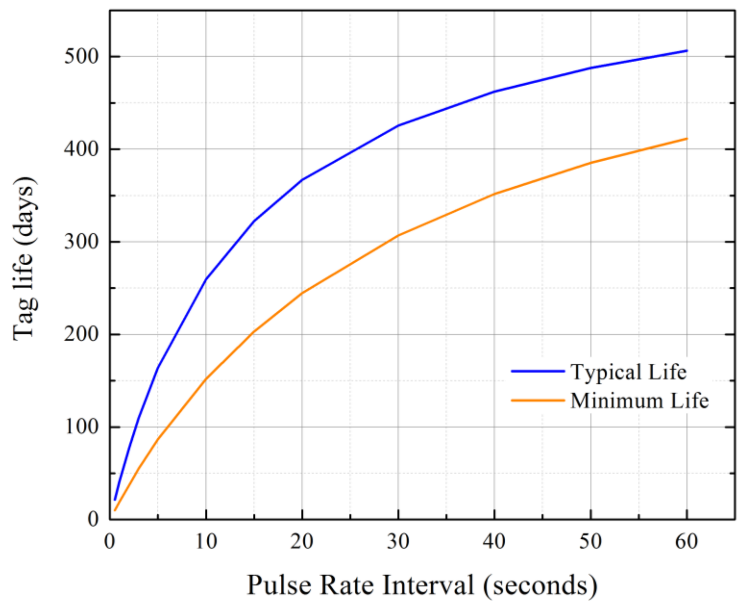


Figure 3.2. Projected tag-life based on pulse rate interval for the downsized JSATS transmitter.

Fish will also be implanted with passive integrated transponder (PIT) tags. PIT tags will be equivalent to the Destron Fearing model TZ1411ST, measuring 12.5 mm length and 2.0 mm width, and weighing 0.10 g in air (0.06 g in water; 0.04 mL volume).

Codespace

Codespace (the set of possible unique codes that are available for acoustic transmissions from tags, beacons, and acoustic releases) must be managed to avoid duplication of codes in use in the CRB. Details concerning codespace management are available in McMichael et al. 2011.

Cabled Receivers

Each modular JSATS cabled array consists of software, a computer, multifunction electronic cards including a global positioning system (GPS) receiver, digital signal processing cards with field programmable logic gate capability, a signal conditioning interface, cables, and up to four hydrophones.

Cabled receiver components are readily available, with the exception of hydrophones with their unique characteristics and the software that controls computer function and signal processing. The software controlling computer function and signal processing is the property of and provided by USACE. Information concerning cabled receiver configuration, setup, and signal processing may be found in McMichael et al. 2011.

Hydrophone Developments, Specification, and Cables

Omni-directional hydrophones, providing a broad range of detection, will be deployed at IHR. These hydrophones will be housed inside an anechoic cone, otherwise referred to as an acoustic baffle, designed to reduce ambient noise levels near operating powerhouses or spillways. Most hydrophones will be deployed in trolley pipes affixed to the tailrace piers (between draft tubes) and concrete walls. A GPS will be used to identify the predetermined hydrophone locations (McMichael et al. 2011). Two hydrophones will be deployed in each trolley pipe (positioned perpendicular to the dam-face at shallow and deep elevations below the water's surface) to provide appropriate geometry to track tagged fish in three dimensions. Specifications for the cabled array hydrophones may be found in McMichael et al. 2011.

Miles of low-voltage signal cable will be routed from the top of the piers to instrument trailers with IHR project staff guidance. Hot-dipped galvanized cable trays will be used in an effort to keep cables organized and to ensure their presence does not impede normal operations at the project. Where cable trays are not ideal for installation, alternatives for routing deck cable will be cleared with IHR project staff.

Autonomous Receivers

Autonomous receivers (ARs) are self-contained receivers that capture messages transmitted by acoustic transmitters implanted in juvenile salmon for this study. The AR detects the transmission with a narrow-band, omni-directional hydrophone. This signal is amplified and filtered, converted to binary data, and integrity checked using cyclical redundancy. When an intact message is received, the message along with time, date, signal strength, and certain environmental data are stored on a compact flash (CF) card. General specifications for an AR may be found in McMichael et al. 2011, along with a detailed operation manual. Information relating to AR deployment and retrieval is available in McMichael et al. 2011 and Titzler et al. 2010.

Data Output Format

Data from the AR are stored on removable media. Information includes a descriptive designation defined by the user, date and time of file creation, serial number of the receiver (serial number, firmware version, file format version), and file start and end times and dates. Physical data (e.g., date, time, pressure, temperature, tilt) are recorded every 15 seconds along with system information (e.g., battery voltage). Tag detections are recorded in text format along with pertinent information from the tag decode (e.g., tag identification, relative signal strength indication, threshold level, and tag frequency bit period).

Fish Injection System

Fish will be injected directly into the turbines via pipes that will be mounted to STS screens upstream of the turbine intake. Full descriptions of these pipes can be found in Section 3.2.1.1.

Inventory

Inventory for all JSATS equipment with a value greater than $300 and not considered expendable will be monitored by CENWW using barcode readers and a common database. The contractor's inventory database will correspond to the CENWW's database. Each piece of equipment will be assigned a deployment location that will be updated throughout the season as maintenance issues arise and hydrophones and/or equipment are replaced or repaired. The inventory will be provided to the CENWW point of contact (POC) annually in December.

3.1.1.2 Procurements

Procurement needs will be communicated with the CENWW POC. Unless noted otherwise, contractor-procured shipments will be delivered to the contractor. The responsible receiving party will enter the procurement into a formal receipt log. Procurements will not be documented as complete until the product or tool has been tested and confirmed to be ready for use in the study.

Components to procure for cabled and autonomous receiver arrays, fish tagging and fish release, and all other components of the AT portion of this study are listed in Appendix B, Table B.1.

Transmitters

The downsized JSATS acoustic transmitters used in this study will be manufactured by the vendor selected by CENWW. The transmitter solicitation will be released by CENWW sometime during the winter prior to field season. For experimental design purposes, it is necessary to have an even distribution of tags from all manufacture dates for a given season. Therefore, the contractor must receive all transmitters for a given tagging season (e.g., spring or summer) prior to the activation of tags for the first tagging date. For example, if 10,000 tags are being used for yearling Chinook salmon releases during spring, all 10,000 tags must be delivered to the contractor or the tag-activation location one week prior to the start of fish collection in each year/season of study. After receipt of all tags, tag lots will be randomly assigned for tagging.

Cabled and Autonomous Receiver Arrays

The cabled arrays include the deployment (trolley) pipes; trolley sleds (for hydrophones); hydrophones; trolley beacons; cables; and computers with detectors, decoders, and hard drives. CENWW will provide (under separate competitive procurement) materials and services for installation of tailrace hydrophone deployment pipes and cable trays. Receiver integration followed by thorough system performance checks will be planned and scheduled prior to delivery to the installation teams in February of the year of study. Autonomous receiver array equipment includes receivers, hydrophones, acoustic releases, anchors, mooring lines, and miscellaneous hardware. Items that are considered *non-competitive* will be procured through the contractor. Autonomous receiver and acoustic release performance checks shall be planned and scheduled prior to delivery to deployment teams in April of the year of study. This work is contingent upon coordination between the Contracting Officer’s Technical Representatives (COTRs), the program manager, and contracts staff for timely execution of procurements.

Acceptance Testing

Acceptance testing of all JSATS components is a necessary part of the preparation process. Transmitters, ARs, and cabled receivers must meet acceptance criteria before field use in each year of study. Detailed information concerning JSATS acoustic transmitter testing, AR testing, and cabled receiver testing may be found in Appendix H of McMichael et al. 2011.

3.1.1.3 Personnel and Logistics

This section details the labor plan for all AT tasks outlined in this IP. The staff required to complete all tasks will be coordinated by the contractor. The contractor may also work with subcontractors to fill some roles.

Labor Plan for Data Collection and Analysis

The number of personnel required for the completion of each task is listed in Table 3.2. The number of individuals required to complete the tasks outlined in the schedule may vary depending on the abilities and commitments of personnel involved.

Table 3.2. Number of individuals at each position level needed to complete each task. This number may vary contingent on personnel's abilities and commitments. All personnel are required to participate in at least one activity within a given task.

Task	Timeline	Specific Activities	Position	Number of individuals required
1-Attend Pre-Work Meetings/Management	10/01/XX-12/15/XX+1	a) Coordinate activities with CENWW district staff b) Coordinate activities with IHR project staff c) Finalize experimental design	Chief Scientist	2
			Senior Biometrician	1
			Senior Biological Scientist	2
			Fishery Biologist	3
2-Preseason/Planning	10/01/XX-03/31/XX+1	a) Procure equipment and supplies b) Acceptance testing of equipment c) Training of personnel d) Staff/equipment planning e) Set-up subcontracts f) Deployment coordination g) Site visits	Chief Scientist	2
			Senior Biometrician	1
			Senior Biological Scientist	2
			Senior Engineer	2
			Biological Scientist	4
			Fisheries Biologist	3
			Biological Science Technician	6

Table 3.2. (contd)

Task	Timeline	Specific Activities	Position	Number of individuals required
3-Deployment/Demobilization	03/01/XX+1-09/30/XX+1	a) Deploy all JSATS equipment b) Deploy/test fish injection system c) Demobilize JSATS equipment d) Demobilize fish injection system	Senior Biological Scientist	3
			Biological Scientist	2
			Fisheries Biologist	2
			Biological Science Technician	4
4-Tagging/Fish Releases	04/28/XX+1-7/15/XX+1	a) Fish collection b) Fish tagging c) Fish release d) Tag activation e) QA/QC f) Daily operations coordination	Biological Scientist	10
			Biological Science Technician	11
5-Data Collection/Processing	04/28/XX+1-12/15/XX+1	a) Archive data b) Cabled receiver downloads c) Autonomous receiver downloads d) Summarize detection event data e) Data diagnostics f) Statistical analysis	Chief Scientist	2
			Senior Biometrician	1
			Senior Biological Scientist	3
			Biological Scientist	2
			Fisheries Biologist	2
			Biological Science Technician	3
6-Prepare Deliverables	08/15/XX+1-12/15/XX+1	a) Prepare preliminary reports b) Prepare annual report	Chief Scientist	2
			Senior Biometrician	1
			Senior Engineer	2
			Senior Biological Scientist	2
			Biological Scientist	5
			Fisheries Biologist	2
			Biological Science Technician	2

3.1.1.4 Training

This section details the training procedures that staff will undergo for tasks outlined in this IP. Training will occur one to four months prior to the start of the spring outmigration. Training will include reviewing detailed standard operating procedures (SOP) for each task that they are involved in and, in some cases, hands-on training.

Fish Surgery Training

One to four months before the start of the spring outmigration, contractor staff and their subcontractors (e.g., Pacific States Marine Fisheries Commission [PSMFC]) will take part in training sessions to become proficient in fish tagging. Surgeons will be trained on subyearling-sized Chinook salmon (smaller fish require the most precision and aptitude) using the most current tagging protocol approved by the Surgical Protocols Steering Committee (USACE 2011). Currently, the tagging protocol does not include specifics related to utilizing the downsized transmitter but is expected to be updated within the next year.

Ideally, surgeon training will begin 2 to 3 months prior to the start of tagging. This will allow time for training (up to 1 week per training session) and results. Fish that are tagged for the practical examination portion of the testing, typically 20 to 75 fish per surgeon depending on surgeon experience level, will be held for at least 2 weeks after implantation to monitor tag expulsion and mortality. In addition, incisions may be graded and photographed after surgery on days 0, 7, and 14. Graded examinations will focus primarily on tissue trauma (e.g., wound inflammation and ulceration, incision openness). Other aspects of the surgical technique (e.g., wound edge alignment) also may be recorded to aid in the evaluation of the surgical trainees. All surgery training exam fish will be held in 15°C to 17°C water to detect improper surgical techniques within the 2-week holding period. Initiating the surgeon training in late winter-early spring will allow time for the re-training of individuals who did not pass the post-surgery examination grading. In addition, some individuals may pass the training but require additional instruction to refine their skills prior to tagging run-of-river fish. Surgeons with satisfactory results from the practical examination (e.g., no transmitter loss) will be members of the team that will tag yearling Chinook salmon and subyearling Chinook salmon smolts for the AT study. Additional surgery practice shall be available at the contractor site shortly before the tagging season for individuals who have passed surgeon training. Therefore, additional permitting to obtain fish for surgeon training is not required. However, an Institutional Animal Care and Use Committee (IACUC) protocol must be approved prior to any fish handling. The IACUC protocol describes all of the methods associated with fish handling (anesthesia, surgery, grading, euthanasia, etc.), the goals of the study, and the methods taken to minimize stress on the fish.

Fish Collection Training

In the fall prior to the year of study, several individuals from the contractor agency will visit the LMN Juvenile Fish Facility (JFF) to observe and participate in preparing the daily sample of fish for training purposes. The Smolt Monitoring Program (SMP) staff and project biologist at LMN will teach these individuals the daily sample data recording protocol (e.g., determining species, run, rear type, calculating percent descaling, identifying diseases, etc.). Approximately 1 to 2 months prior to the start of tagging, contractor staff will use Microsoft PowerPoint presentations to train other staff and/or subcontractors who will participate in fish collection. Pictures will depict identifiable species/stock characteristics, examples of common diseases, predation marks, body and head injuries, etc. In addition, trainees will learn the acceptable levels of injury and disease for fish selected for surgical implantation. More importantly, they will learn which fish are not fit for surgery and therefore should be "excluded" and returned to the river. All acceptance/exclusion criteria used in this study will follow the guidance outlined in the USACE Surgical Protocols document (USACE 2011). If possible, individuals who will be sorting daily samples and collecting fish for tagging will also have an opportunity for hands-on practice on the sample line at LMN prior to the start of tagging.

Anesthesia Training

Anesthetizing fish, an important aspect of surgical implantation, can have negative effects on fish recovery if administered incorrectly. Therefore, anesthesia training will be provided to all individuals who will be anesthetizing fish prior to and during tagging. Contractor staff well-skilled in fish anesthesia techniques will provide training to other contractor staff and/or subcontractors at the contractor's facility or other location coordinated with CENWW. Trainees will observe and participate in anesthetizing both yearling and subyearling-sized Chinook salmon using a dose of 80 mg/L tricaine methanesulfonate (MS-222) buffered with 80 mg/L sodium bicarbonate ($NaHCO_3$). Through practice, the trainees will learn to identify signs indicative of sedation (e.g., loss of equilibrium, immobility, reduced opercular movements) which are characteristic of Stage 4 anesthesia (Summerfelt and Smith 1990) and for these fish stocks typically occur within 2 to 3 minutes, the length of time generally accepted as causing fewer negative effects (USACE 2011). Trainees will become accustomed to monitoring the water temperature and anesthesia times for all fish to determine when these parameters fall outside of the acceptable ranges (i.e., ±2°C from the initial temperature and 2 to 3 minutes, respectively). When this occurs, anesthetist trainees will recognize that anesthesia baths need to be remade. Surgeons will learn to identify fish that are too deeply or too lightly sedated on the surgery table and to modify the maintenance anesthesia dose (administered during the surgery), if necessary. Water temperature and fish stock can influence the effect MS-222 has on fish sedation (e.g., extremely cold water temperatures can lengthen the time required for fish sedation at a given dosage); therefore, anesthetists will monitor anesthesia induction times and adjust the dosage to keep within the 2- to 3-minute time frame.

3.1.1.5 Deployment

This section details the deployment procedure for all equipment to be installed or located at or near IHR for the AT survival study. The locations of autonomous and cabled receiver array systems will be dictated primarily by the dam location, forebay and tailrace hydraulic influence (Appendix C), and professional judgment concerning desirable distances between fish release locations and detection arrays to avoid dead fish detections. Precise locations of autonomous arrays are influenced secondarily by the morphometric characteristics of channel cross sections to maximize the performance of ARs. Deep narrow cross sections will be preferred over wide and/or shallow cross sections.

Cabled Receiver Arrays

Downstream Dam-Face

JSATS cabled array systems have been deployed on upstream dam-faces for many studies in the lower Snake and Columbia rivers (2008 – 2013). These systems proved to be highly successful with >99% detection efficiency. Additionally, cabled array systems were deployed on the downstream dam-face for a study in 2013 in the tailrace of IHR (Ingraham et al. 2014). Based on this experiment, it was concluded that three-dimensional position data of a tagged fish with sub-meter accuracy would be possible to attain in the IHR tailrace. This study will employ the deployment design outlined in Ingraham et al. 2014. In this plan, two hydrophones will be deployed into the tailrace at nine locations across IHR (Figure 3.3). At each location, one hydrophone will be placed at a shallow water depth and one hydrophone will be placed deeper in the water column.

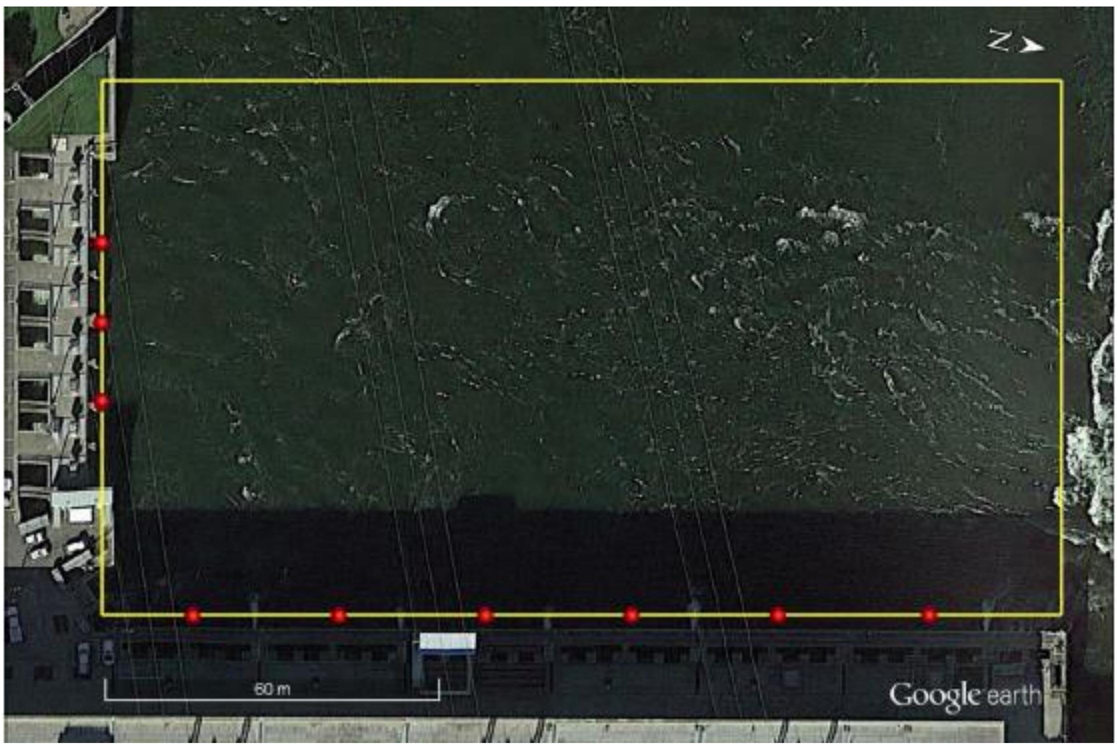


Figure 3.3. Location of the cabled hydrophones in the tailrace of IHR. A deep and shallow hydrophone will be deployed at each location (red dot).

Trolley pipes will need to be installed on the tailrace side of the IHR powerhouse (Figure 3.4) during the fall or winter prior to the first study year. Six trolley pipes will be mounted to the pier dividing the two draft tubes of each turbine unit. By placing the trolley pipes in these locations, the flow effect and impact of noise generated from the water exiting the draft tubes would be minimized. Three trolley pipes will be deployed near the fish pumps on every other pier. For deployment, hydrophones will be mounted on the arms of stainless steel (SS) trolley sleds, which will then be deployed in the trolley pipe and lowered to a predetermined elevation via a SS cable. There will be two trolley sleds per pipe, one deep and one shallow, each with one hydrophone attached. At every third trolley pipe a battery-powered beacon will also be attached to one of the two trolley sleds, alternating between a shallow and deep deployment. The beacons will transmit a 156-dB signal at 60-s intervals. These signals will be used to verify array geometry and ensure hydrophones are properly decoding acquired acoustic signals from tagged fish. The JSATS hardware and software specifications are described in detail in McMichael et al. 2011.

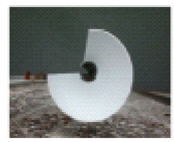
(a)  (b) 

Figure 3.4. (a) Example of an 80-ft trolley pipe mounted on a dam face pier; (b) top view of a slotted 4-inch diameter trolley pipe. Similar trolley pipes will need to be attached to IHR tailrace piers.

The JSATS data cables will be connected directly to each deployed hydrophone, zip-tied to the trolley steel cable, and run up the trolley pipe to the tailrace deck, where they will be routed to data acquisition systems located in an environmentally controlled trailer located near the tailrace deck (Figure 3.5). All hydrophone cables will be placed within cable trays.

Figure 3.5. Location of an 8 ft x 12 ft (or larger) environmentally controlled equipment trailer to be installed near the tailrace deck of IHR. NOTE: The trailer is not to scale but indicates the approximate location.

It is preferred to install cable trays along the downstream side of the safety rail (Figure 3.6Figure 3.6). U-bolts or other fasteners will be used to secure each cable tray to the center of the safety rail and above any previously installed electrical conduit. Cable trays will also be cut to the same length, or less, of each removable safety rail so that safety rails can be removed, if needed, in the future. The cable trays will end prior to crossing obstacles (i.e., electrical boxes, brackets), then continue after the obstacle. Where cables cross walkways, the cables will be placed underneath custom-fit “speed bumps” to avoid creation of a tripping hazard and to protect the cables from traffic. Specific deployment configuration information is detailed in McMichael et al. 2011.

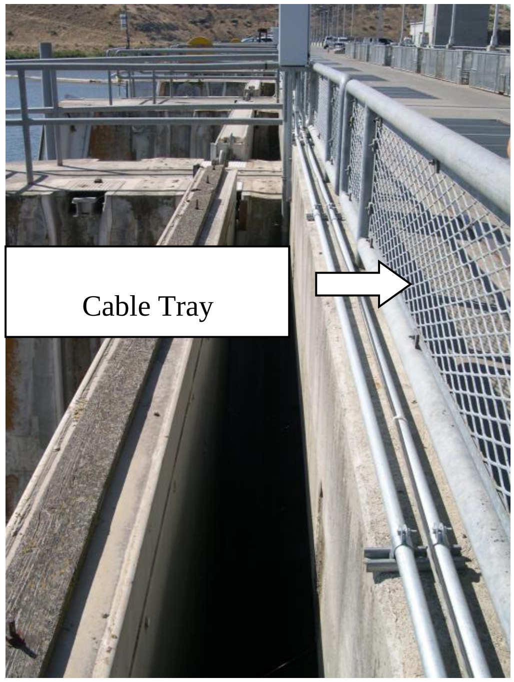


Figure 3.6. Example of proposed cable tray location on the safety rail. The cabled trays will be installed on the downstream side of the safety rail on the tailrace side of the dam.

Autonomous Receiver Arrays

ARs will be deployed at two strategically located sites along transects across the Snake and Columbia rivers to meet the objectives of the IHR Turbine Evaluation Study (Figure 3.7). Groups of ARs are termed "arrays" because they operate in conjunction with each other to detect fish moving past a cross section of river. Tables in Appendix D list the waypoint name, latitude, and longitude of all ARs that will be deployed during the study period. Specific deployment details (e.g., methods) are available in McMichael et al. 2011 and Titzler et al. 2010.

A schematic of the experimental design for the IHR Turbine Evaluation Study is shown in Figure 2.1.

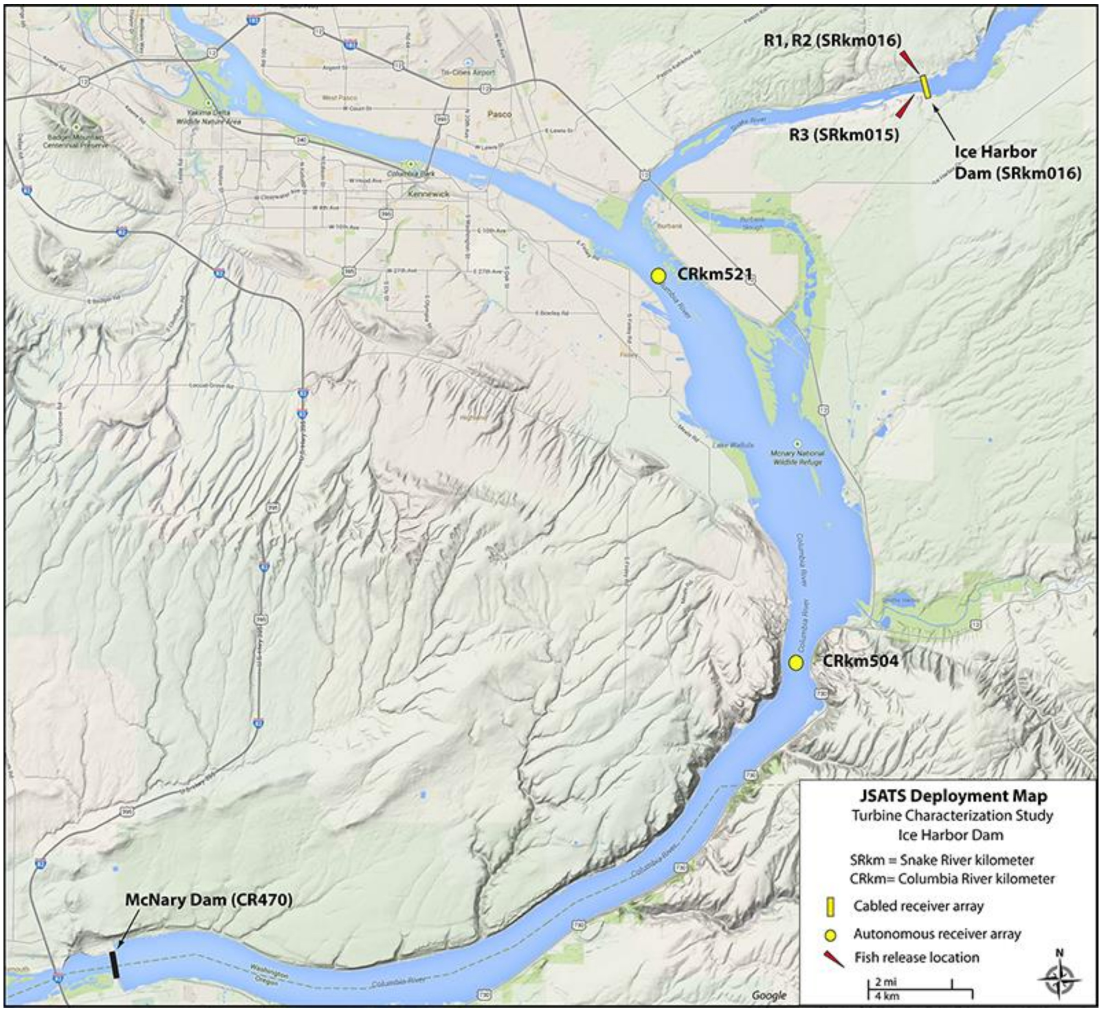


Figure 3.7. Map of autonomous array and fish release locations.

Fish Injection System

Deployment of the turbine intake injection system will occur as described in Section 3.2.1.5.

The lateral location(s) and position(s) of fish injection pipes will be determined by CENWW staff prior to the initiation of the study and communicated to the study contractor. Release locations will be determined and verified through physical hydraulic model investigations at the Engineer Research and Development Center (ERDC) 1:25 scale model of Ice Harbor turbine, located in Vicksburg, Mississippi, prior to beginning of the field evaluation. Additional injection system equipment, for example injection pipes for control fish releases, locations will be dictated primarily by the study location on the dam.

3.1.2 Data Collection

Information related to the fish tagging process is described below.

3.1.2.1 Fish Collection, Tagging, and Release

Several months before the start of the spring outmigration, contractor staff and subcontractors will undergo training sessions in the surgical implantation of acoustic transmitters into juvenile salmonids (Section 3.1.1.4). Surgeons who have satisfactory results (e.g., no transmitter loss) from the practical examination will be members (or alternates) of the team that will tag yearling and subyearling Chinook salmon smolts during the study period. Fish will be collected for this study in accordance with established permitting requirements using the sampling methods commonly used at juvenile fish facilities, as described below. Tagging protocols will follow those developed by Dr. R. Brown and colleagues (USACE 2011, or a more recent version).

Description of the Tagging Site

All fish will be collected and tagged at the LMN JFF and will be released according to a specific schedule into the turbine unit being tested within a given season. The LMN JFF collects fish passing through the juvenile bypass system (JBS); therefore, all fish to be tagged for the AT survival study will be collected from the JBS. Depending on the abundance of fish passing through the JBS, the sample rate will be set to collect fish for inclusion in this survival study. Juvenile salmonids begin moving through the JBS after they are screened from the upper third of the river flow passing into six turbines at LMN. Most smolts are diverted into gatewell slots located above each turbine intake (three per turbine). From the gatewell slot, most smolts pass through a 0.3-m-diameter orifice into a collection channel that runs the length of the powerhouse. After considerable dewatering, insulated pipes deliver smolts to monitoring facilities where they may be sampled and examined to evaluate their health or condition. Sampled fish typically are returned to the river in an outfall pipe emptying into fast water in the tailrace. However, fish sampled and selected for inclusion in the AT portion of this study will be diverted to fish holding tanks set up by the contractor agency.

In the event that permits to use run-of-the-river fish are not issued for this study, smolts will be obtained from a local hatchery to be used in this study. Hatchery fish will be transported to LMN in transport trucks supplied with oxygen. Oxygen tanks (2,200 psi) will be secured to the bed of the transport truck and will maintain dissolved oxygen levels in the totes between 80% and 110%. Water temperature will be maintained in the totes with the addition of ice made from river water, if necessary. During transport, water temperature and dissolved oxygen will be monitored via an instrument cable running from the tote to inside the transport vehicle. Untagged fish will be held in fish holding tanks with flow through river water at LMN prior to surgery.

A mobile office trailer that has been modified for fish holding and surgeries will be used for tagging at LMN. It will be located on the south side of the JFF and will have water and power access nearby. Power and ground cable installation will be coordinated with USACE project electricians. Fish holding tanks will be adjacent to the tagging trailer. These tanks will be supplied with flow through river water and monitored for water temperature and dissolved oxygen levels. Further details concerning the tagging trailer, fish holding tanks, and utility locations are available in McMichael et al. 2011.

Federal and State Permitting

Applications for both federal (National Marine Fisheries Service; NMFS) and state (Washington Department of Fish and Wildlife [WDFW]) scientific collection permits and WDFW fish transport permits will be submitted in the winter prior to the study year. The ability to tag smolts is contingent on obtaining approval from NMFS and WDFW to collect and mark the large number of fish suggested in the experimental design. After permits have been obtained, records will be kept on all smolts handled and collected (both target and non-target species) for permit accounting. Collections will be conducted in conjunction with routine sampling at the monitoring facilities to minimize handling impacts. Annual reports of the level and number of fish "taken" (tagged or handled in the study) which are required by the authorizing agencies will be provided by the contractor by the report deadlines.

Fish Collection

Fish will be collected from April through early July in the study year, at the LMN JFF via the JBS. Fish diverted from the JBS are held in a sample tank for up to 24 hours prior to examination. Upon commencement of sampling, MS-222 will be added to the tank chamber by SMP staff to obtain a concentration of approximately 65 mg/L, producing the desired level of sedation. Anesthetic concentrations may be adjusted throughout the season by SMP staff to reflect fish response to MS-222, the number of fish, species composition, and water temperature. Once anesthetized, fish will be flushed through the exit valve to the sorting trough inside the lab.

Once the fish are in the sorting trough, SMP staff will sample all fish and fish of the target species/stock will be passed to contractor staff to select fish for study use. Sedation of fish will be maintained throughout the sorting process with MS-222 concentrations between 40 and 45 mg/L. Fish will be selected for the current study by the contractor based on the acceptance/exclusion criteria listed below (USACE 2011). Individual fish are excluded to avoid violating the statistical design assumptions, which state that tagged individuals should be a representative sample from the population of inference and that all tagged individuals alive at a sampling location have the same probability of surviving until release. If a physical anomaly/malady is observed in more than 5% of the sorted fish sample, the next day's fish with similar conditions will be accepted in the collection. The lead contractor biologist and a USACE representative should be contacted in writing before implementing any change in practice. These criteria have been reviewed and approved by CENWW for AT survival studies.

Fish is available for tagging if it:	Is a yearling spring Chinook salmon collected in the spring, or a subyearling fall Chinook salmon collected in the summer
	Is between 95- and 300-mm fork length
	Has an intact or clipped adipose fin
	Is tagged or not tagged with coded wire or elastomer tag
	Does not show signs of prior surgery (e.g., radio tags, sutures, or PIT-tag scars)
	Does not have a positive reading when put through a PIT-tag reader
Fish is excluded if it:	Is moribund or emaciated
	Has malformations such as spinal deformities
	Exhibits descaling greater than 20% on any side of the body
	Has physical injuries severe enough to impede performance, such as:
	- Opercular damage (missing or folded over greater than 75%)
	- Exophthalmia (pop-eye)
	- Eye hemorrhages (greater than 10% of the eye); fish with

cataracts will not be rejected

- Head or body injuries (e.g., emboli, hemorrhages, lacerations)
- Fins torn away from body and/or Stage 5 erosion

Shows evidence of infections, symptoms include:

- Fungal infections on the body surface
- Gill necrosis
- Open lesions on the body or fins
- Swollen body
- Ulcers
- Copepod parasites on the eyes or gills (greater than 25% coverage)

During sorting and tagging, contractor staff will use a data sheet (Table 3.3) to record the number of fish handled each day by species/stock and status (i.e., clipped or unclipped). Of the total number of target fish handled, they will record the number of fish that were not available for tagging (i.e., < 95 mm or > 300 mm, previously tagged) by species/stock and status. Fish that are excluded based on condition (i.e., are moribund or emaciated, have skeletal deformities, have descaling > 20% on one side of the body, have physical injuries, or show evidence of infections) will be tallied by species/stock and status. After each collection session, the percent of fish rejected will be calculated and recorded for the day. A cumulative total for the season will also be determined.

Table 3.3. Example data sheet to record the number of fish from the target stock handled each day in the JFF, those not available for tagging, and those excluded for condition reasons.

Date	Target Number of Fish	Sample Rate	Tank	# of CH0 Accepted		# of CH0 Not Accepted		Clipped CH0 Not Accepted for Tagging							Unclipped CH0 Not Accepted for Tagging							Comments
				Clipped	Unclipped	Clipped	Unclipped	< 95 mm	Previously tagged	Descaling >20%	Physical injuries	Disease/ infection	Skeletal deformities	Moribund	< 95 mm	Previously tagged	Descaling >20%	Physical injuries	Disease/ infection	Skeletal deformities	Moribund	
		_____% ___:00 - ___:00	A																			
		_____% ___:00 - ___:00	B																			
		_____% ___:00 - ___:00	A																			
		_____% ___:00 - ___:00	B																			
		_____% ___:00 - ___:00	A																			
		_____% ___:00 - ___:00	B																			
		_____% ___:00 - ___:00	A																			
		_____% ___:00 - ___:00	B																			
		_____% ___:00 - ___:00	A																			
		_____% ___:00 - ___:00	B																			
		_____% ___:00 - ___:00	A																			
		_____% ___:00 - ___:00	B																			
		_____% ___:00 - ___:00	A																			
		_____% ___:00 - ___:00	B																			

Fish selected for the current study will be held for 12 to 36 hours in holding tanks prior to surgery according to methods and conditions outlined in USACE Surgical Protocols (USACE 2011). In the spring, all other fish will be returned to the river below the dam. In the summer, all other fish will be returned to the river below the dam or diverted to a recovery tank where they will be held until they are loaded onto a barge and transported downstream of Bonneville Dam before they are returned to the river.

The number of fish that need to be collected each day will depend on the number of fish that are scheduled to be tagged on the following day. Contractor staff will communicate the daily collection quotas to USACE and SMP staff prior to the beginning of tagging to ensure that target fish collections can be made without impacting JFF operations. If sample numbers are lower than expected, contractor staff will communicate that to USACE and SMP staff and work towards a solution (e.g., increase sampling rate).

Fish Tagging

Several steps will be used in the tagging process to minimize the negative influence of handling, including the following:

- A new sterile scalpel blade (incision method) or a sterile needle (injection method) will be used for each surgery.
- A synthetic water conditioner (PolyAqua) will be used liberally on the surgical pad and other contact surfaces (measuring board, weigh boat, etc.) to counteract disruption to mucus membranes during handling and surgical procedures.

The morning after collection, a team of 7 to 10 people will participate in the tagging process to reduce the handling time from pre-surgery netting to post-surgery recovery. A daily goal for all fish tagging is completion within a 5- to 10-h period, depending on the number of fish to be tagged. Prior to surgery, fish will be netted from the holding tanks and placed in buckets filled with aerated river water. Three to five fish will be placed in an anesthetic bucket prepared using buffered MS-222 in quantities of 80 mg/L for Chinook salmon. After losing equilibrium, the fish will be immediately weighed, measured for length, and both an acoustic and PIT-tag will be assigned.

At the time of this IP, the downsized JSATS transmitter has not been used in a full-scale field study and laboratory testing is still ongoing to determine the best method for implantation of the transmitter and the minimum size of fish that can be tagged with it. The IHR Turbine Evaluation Study will employ the method that is approved for use in field studies (specifically performance study evaluations) by the USACE and the Region. It is likely that the approved method will be injection of the transmitter into the body cavity with an 8-gauge needle or inserting the transmitter into the body cavity via a 3-mm incision on the right side of the fish’s body. It is currently unknown whether or not a suture will be needed to close the injection wound or incision.

Injection Method

The acoustic transmitter and PIT-tag loaded into an 8-gauge SS hypodermic needle, and a fish sedated to Stage 4 anesthesia will be provided to the surgeon. The fish will be held in the hand (typically the non-dominant hand) of the surgeon with the left side of the fish against the palm and the head directed towards the surgeon. With gentle pressure on the fish's head and abdomen, the surgeon will insert the tip of the needle (aimed posteriorly) into the skin of the fish, with bevel down, at an angle of 30-40 degrees. The insertion point will be at the end of the pectoral fin, offset from the linea alba by several millimeters (Cook et al. 2014). Once the abdominal tissue is cut, the tags will be inserted into the peritoneal cavity with the PIT-tag entering the cavity first followed by the acoustic transmitter to reduce the likelihood of the PIT-tag being shed.

Incision Method

The acoustic transmitter, PIT-tag, and a fish sedated to Stage 4 anesthesia will be provided to the surgeon. The fish will be placed right side up on the surgery table/pad which is coated with the PolyAqua water conditioner. With the fish facing right side up, a scalpel will be used to make an incision 2-3 mm above the linea alba where the tip of the pectoral fin lies against the body. The incision will be 3-mm in length and made by cutting in the posterior direction (Cook et al. 2014). A PIT-tag will then be inserted into the peritoneal cavity followed by an acoustic transmitter.

After tagging, fish will be placed into specially designed 22.7-L buckets and transferred to a post-surgery holding trough which is supplied with flow through river water. Fish will be held inside the buckets in these tanks for 12 to 36 h (USACE 2011) to allow time for recovery from surgery before being transported and released to the river.

Holding, Transport, and Release

Specially designed 22.7-L release buckets will be used for holding and transporting fish following surgery. The top half of each bucket will be perforated with 0.8-cm-diameter holes that will allow the flow-through of fresh river water when the buckets are submerged in transportation and holding tanks. The non-perforated bottom half of the bucket will provide fish sanctuary in approximately 11 L of water when not submerged in a larger tank (e.g., when the bucket is being carried between holding and transportation tanks). To reduce confinement stress, fish will be kept below maximum density thresholds of 50 g/L (USACE 2011). To reduce transportation and handling stress, fish will be placed in release buckets immediately following surgery and will remain in the same bucket until fish are released into the turbine.

After surgery, 5-6 fish will be placed inside each perforated release bucket supplied with a continuous flow of river water. Once all fish have regained equilibrium, perforated buckets will be covered with individually numbered lids and carried to a larger holding trough supplied with a continuous flow of river water. The water level will be adjusted to maximize water volume through the buckets while keeping the buckets in an upright position. Fish will be held for 12 to 36 h prior to their release into the turbine, maintaining dissolved oxygen levels between 80% and 110% saturation, total dissolved gas levels less than 105%, and water temperature within 2°C of the ambient river temperature from which fish were acclimated. A sensor for monitoring water level, temperature, and dissolved oxygen will be installed within the holding trough. Where possible, the sensor system will be set up to automatically send a text message to staff if physiochemical conditions approach threshold limits. An alarm will also sound which will alert USACE staff of the problem. Additionally, at least one contractor staff will be onsite at LMN 24 hours per day and will check water levels in holding tanks and troughs hourly.

After the post-surgery recovery period (i.e., 12 to 36 h), buckets will be removed from post-surgery holding troughs and loaded into 675-L polyurethane foam-insulated totes measuring approximately 112 cm long by 99 cm wide by 69 cm tall and filled with river water to a depth of 61 cm on the transport vehicle (truck or flatbed trailer; McMichael et al. 2012). Each tote will hold up to nine buckets. Oxygen tanks (2,200 psi) will be secured to the bed of the transport truck and will maintain dissolved oxygen levels in the totes between 80% and 110%. Temperature will be maintained in the totes with the addition of ice made from river water, if necessary. During transport, temperature and dissolved oxygen will be monitored via an instrument cable running from the tote to inside the transport vehicle.

Upon arriving at the release site boat launch, perforated buckets will be unloaded from the insulated tote at the turbine release pipe on the intake deck (R_1), tailrace release pipe on the tailrace deck (R_2) or into the bypass pipe at the IHR JFF (R_3). All buckets will be shaded to minimize solar heating and light disturbance. Water quality parameters (temperature, dissolved oxygen, and total dissolved gas) will be monitored within a subset of the buckets to ensure water quality standards are being met. Prior to release, fish status in the buckets will be monitored and all dead or moribund fish will be removed from the bucket and identified by PIT-tag. Moribund fish will be euthanized with a 250-mg/L solution of MS-222 and then staff will cut their gill arches. Dead fish will not be released with their respective release groups; rather, the tags will be returned to the tagging site. Prior to release, buckets will be inspected closely for dropped PIT or acoustic tags by release personnel. The probability of release personnel identifying dropped tags will be assessed by placing dummy PIT and acoustic tags in randomly selected buckets. For R_1 and R_2 releases, buckets will be lowered into the release tank and tipped into the water so that fish can swim out. The release pipe will then be flushed with water, forcing fish to pass down the release pipe. For R_3 releases, fish will be released into the bypass pipe to allow for determination of the combined fish survival of the new turbine and the immediate influence of the region of the draft tube modifications. For all releases, crew members will record the release point, bucket number, time of release, and related information (See Fish Release Data Sheet in McMichael et al. 2011). Records will indicate release time to the nearest minute in Pacific Daylight Time (PDT).

Tagged fish will be transported from the tagging site to the three release sites (i.e., turbine release pipes, control release pipes, and downstream release site) based on the fish release schedule (Table 3.4 and Appendix E, Table E.1 for yearling Chinook salmon; Table 3.5 and Appendix E, Table E.2. for subyearling Chinook salmon). Tank water temperature and dissolved oxygen concentration will be measured and recorded before, during, and after transportation to ensure levels remain within the aforementioned parameters (Table 3.6).

Table 3.4. Example fish release schedule for yearling Chinook salmon by release block. This schedule reflects the release type, sample size, and release time. Release type corresponds to the following location: R_1 = directly into turbine via release pipe, R_2 = directly into tailrace via release pipe on downstream side of dam, and R_3 = release into tailrace approximately 250 ft downstream of the dam.

Release	R1		R2		R3		Dead	
Block	N	Release Time	N	Release Time	N	Release Time	N	Release Time
1	57	4/28/2017 5:00	57	4/28/2017 5:00	57	4/28/2017 5:30	2	4/28/2017 5:00
2	56	4/30/2017 11:00	56	4/30/2017 11:00	56	4/30/2017 11:30	2	4/30/2017 11:00
3	56	5/2/2017 17:00	56	5/2/2017 17:00	56	5/2/2017 17:30	2	5/2/2017 17:00
4	56	5/4/2017 21:00	56	5/4/2017 21:00	56	5/4/2017 21:30	2	5/4/2017 21:00

Table 3.4. (contd)

Release Block	R1		R2		R3		Dead	
	N	Release Time	N	Release Time	N	Release Time	N	Release Time
5	56	5/6/2017 5:00	56	5/6/2017 5:00	56	5/6/2017 5:30	2	5/6/2017 5:00
6	57	5/8/2017 11:00	57	5/8/2017 11:00	57	5/8/2017 11:30	2	5/8/2017 11:00
7	56	5/10/2017 17:00	56	5/10/2017 17:00	56	5/10/2017 17:30	2	5/10/2017 17:00
8	56	5/12/2017 21:00	56	5/12/2017 21:00	56	5/12/2017 21:30	2	5/12/2017 21:00
9	56	5/14/2017 5:00	56	5/14/2017 5:00	56	5/14/2017 5:30	2	5/14/2017 5:00
10	56	5/16/2017 11:00	56	5/16/2017 11:00	56	5/16/2017 11:30	2	5/16/2017 11:00
11	57	5/18/2017 17:00	57	5/18/2017 17:00	57	5/18/2017 17:30	2	5/18/2017 17:00
12	56	5/20/2017 21:00	56	5/20/2017 21:00	56	5/20/2017 21:30	2	5/20/2017 21:00
13	56	5/22/2017 5:00	56	5/22/2017 5:00	56	5/22/2017 5:30	2	5/22/2017 5:00
14	56	5/24/2017 11:00	56	5/24/2017 11:00	56	5/24/2017 11:30	2	5/24/2017 11:00
15	56	5/26/2017 17:00	56	5/26/2017 17:00	56	5/26/2017 17:30	2	5/26/2017 17:00
16	57	5/28/2017 21:00	57	5/28/2017 21:00	57	5/28/2017 21:30	2	5/28/2017 21:00

Table 3.5. Example fish release schedule for subyearling Chinook salmon by release block. This schedule reflects the release location, sample size, and release time. Release type corresponds to the following location: R_1 = directly into turbine via release pipe, R_2 = directly into tailrace via release pipe on downstream side of dam, and R_3 = release into tailrace approximately 250 ft downstream of the dam.

Release Block	R1		R2		R3		Dead	
	N	Release Time	N	Release Time	N	Release Time	N	Release Time
1	64	6/1/2017 5:00	64	6/1/2017 5:00	64	6/1/2017 5:30	2	6/1/2017 5:00
2	64	6/3/2017 11:00	64	6/3/2017 11:00	64	6/3/2017 11:30	2	6/3/2017 11:00
3	64	6/5/2017 17:00	64	6/5/2017 17:00	64	6/5/2017 17:30	2	6/5/2017 17:00
4	63	6/7/2017 21:00	63	6/7/2017 21:00	63	6/7/2017 21:30	2	6/7/2017 21:00
5	64	6/9/2017 5:00	64	6/9/2017 5:00	64	6/9/2017 5:30	2	6/9/2017 5:00
6	64	6/11/2017 11:00	64	6/11/2017 11:00	64	6/11/2017 11:30	2	6/11/2017 11:00
7	63	6/13/2017 17:00	63	6/13/2017 17:00	63	6/13/2017 17:30	2	6/13/2017 17:00
8	64	6/15/2017 21:00	64	6/15/2017 21:00	64	6/15/2017 21:30	2	6/15/2017 21:00
9	64	6/17/2017 5:00	64	6/17/2017 5:00	64	6/17/2017 5:30	2	6/17/2017 5:00
10	63	6/19/2017 11:00	63	6/19/2017 11:00	63	6/19/2017 11:30	2	6/19/2017 11:00
11	64	6/21/2017 17:00	64	6/21/2017 17:00	64	6/21/2017 17:30	2	6/21/2017 17:00
12	64	6/23/2017 21:00	64	6/23/2017 21:00	64	6/23/2017 21:30	2	6/23/2017 21:00
13	63	6/25/2017 5:00	63	6/25/2017 5:00	63	6/25/2017 5:30	2	6/25/2017 5:00
14	64	6/27/2017 11:00	64	6/27/2017 11:00	64	6/27/2017 11:30	2	6/27/2017 11:00
15	64	6/29/2017 17:00	64	6/29/2017 17:00	64	6/29/2017 17:30	2	6/29/2017 17:00
16	64	7/1/2017 21:00	64	7/1/2017 21:00	64	7/1/2017 21:30	2	7/1/2017 21:00

Table 3.6. Water quality parameters to be maintained during pre- and post-surgery holding periods.

Parameter	Minimum	Maximum
Water temperature	Ambient river - 2°C	Ambient river + 2°C
Dissolved oxygen	80%	110%
Total dissolved gas	Not applicable	105%

For "dead fish releases" live fish will be surgically implanted with a JSATS transmitter, euthanized (250 mg/L MS-222), have their gill arches severed, and be released directly into the control fish release pipes from the deck of IHR for each release block to evaluate the assumption that fish killed during dam passage do not passively drift far enough to be detected by the primary or secondary autonomous arrays. Approximately 32 dead fish of each stock will be released at IHR. These fish will need to be intentionally sacrificed. Additional ~1% of tagged fish from each species/stock (27-30 yearling Chinook salmon, and 33-36 subyearling Chinook salmon depending on the number of surgeons) will be sacrificed to monitor surgeon performance throughout the season. Every two to three days, one fish of each stock per surgeon (total of 3 to 6 surgeons) will be selected for evaluation of seasonal surgeon performance.

Dr. John Skalski (University of Washington) will be consulted if logistical constraints occur that may affect the experimental design of this study. However, a contingency plan has been defined as follows:

1. In the event that not enough fish are collected to meet target sample sizes for a given release group, all efforts will be made to balance sample sizes among release type (e.g., R_1, R_2, and R_3) within that release group. Additional fish will be tagged for subsequent release groups to make up for numbers of fish not tagged due to previous low sampling events.
2. If a fish release cannot be completed due to environmental conditions (or other constraints), fish will be released from the boat at a location as close as safely possible to the original position.

3.1.2.2 Data Downloading

Data will be downloaded from cabled receiver array data acquisition machines and collected from ARs during the study.

Cabled Receiver Systems

Maintaining a continuous string of JSATS acoustic data with minimal gaps is critical for ensuring high detection efficiencies and for retaining the ability to track the data in 3D throughout the collection period. Data loss can occur due to loss of power to acquisition machines, hydrophone failure, or unforeseen events. To minimize this data loss, cabled receiver array data acquisition machines will be checked at minimum twice daily, starting on the first day of fish release and continuing until all fish have migrated through the study area (approximately 2 to 3 weeks after the last fish release). This twice daily check on each individual system performance will be annotated on a system check sheet (Table 3.7) and any interruption in the data collection will be noted in a logbook with the reason for occurrence. Big Brother, a commercial software package running on the server for each cabled receiver, will monitor the performance of the connected hydrophones (e.g. current background noise level) and the overall cabled receiver system status (e.g. detector/decoder software running properly, adequate hard drive space, etc.). At any time staff members can check the current status of all of the cabled receivers using a web-based interface. If a problem is detected by the Big Brother software alerts containing relative details are sent to staff through email or text messages every 15 minutes until the issue is resolved. In addition, if the cabled receiver fails to report its status (i.e., a power loss event) an alert is sent to staff. Each cabled receiver is connected to a backup power supply to prevent momentary power losses. In the event of a prolonged power outage that exceeds the capacity of the backup power supply and results in the system shutting once power is returned the system will automatically power itself on and resume data collection.

Table 3.7. Example of a daily system check sheet for cabled arrays.

Date & Time	Staff	C: Space	E: Space	F: Space	CH 1-2 Rx value	CH 1-2 Rx rate	CH 1-2 rate - avg	CH 3-4 Rx value	CH 3-4 Rx rate	CH 3-4 rate - avg	CH 1 volt	CH1 volt - avg	CH1 Beacon	CH2 volt	CH2 volt - avg	CH2 Beacon	CH3 volt	CH3 volt - avg	CH3 Beacon	CH4 volt	CH4 volt - avg	CH4 Beacon	Notes

In addition to the twice daily checks of the cabled array systems, data acquired from the acquisition machines will be downloaded once a week at IHR. The data being downloaded will include processed data (.com files), unprocessed data (.bwm files) and decoded data (.csv files). Both processed data and unprocessed or “raw” data will be directly saved to an internal hard drive in the acquisition machine. These internal drives will be subsequently removed for transfer to the contractor office and new hard drives will be installed. The decoded data will be transferred onto a portable universal serial bus (USB) drive and shall be archived in two separate locations. The daily system check sheets described above will be collected on the day of the data downloads and brought back to the Richland office to be archived. Logbooks containing detailed information on any changes, issues, or ancillary information for each system will also be maintained throughout the data collection season and will be brought back to the Richland office to be scanned and archived every few weeks.

Autonomous Receivers

Data will be collected from ARs every 2 weeks from early May through mid-August when the receivers are recovered to replace batteries and download data. To recover JSATS receivers, a top-side command control unit (direct-current–operated transponder interrogator and receiver) will be used to transmit a unique acoustic signal to each acoustic release. This code signals the release to open, allowing the positively buoyant receiver assembly to ascend to the surface. Occasionally the receiver and/or mooring can become fouled, preventing the receiver assembly from detaching from the anchor when the acoustic release is activated. When this happens, alternative methods are used to retrieve the receiver. In most cases, a grappling hook or pinch bar is dragged in an effort to snag the anchor or receiver mooring and then a davit with a hydraulic or electric winch is used to lift the receiver to the surface. To help minimize data loss due to temporary absence of a receiver at a recovery location, a previously activated receiver is deployed immediately (typically within <5 minutes) following the recovery of each receiver and before the recovery of the next receiver within the array.

After each autonomous receiver is recovered, the outside of the receiver is dried with a towel before it is opened. Once open, a data cable is connected to the receiver’s board set while the batteries are still connected, providing power to the receiver. Next, a record of both receiver and GPS clock times (hh:mm:ss) at one instant is taken to allow for subsequent calculation of a clock offset (receiver time – GPS time) in seconds. Then, the CF card is ejected from the receiver’s board set, and placed in a USB card reader so that comma-separated-variable (csv) data files can be copied from the card to a laptop computer. The entire data file will be viewed in a text editor to verify that the receiver collected data throughout its deployment, records were continuous, and records included time stamps and tag detections. If data near the end of the file include only 15-s time stamps or few to no tag detections with a functional battery, the receiver top will be replaced with a previously tested and accepted receiver. The CF card will not be erased and wiped until data on the laptop have been archived in more than two locations.

3.1.3 Data Management and Analysis

The varied and numerous sources of data that must be combined for successful analysis of a large AT survival study requires careful data collection and management, efficient data processing, and powerful analysis tools. This section describes how those functions are achieved for this study.

Several foundational types of data must be collected to support the estimation of survival and related fish passage metrics. These data include information on tags (fish) released, receivers deployed, and tag code transmissions received. In addition to those field data, tag-life data are collected in the laboratory to support survival analysis. Appendix J of McMichael et al. 2011 describes the data formats for input and archive data files.

3.1.3.1 Tags Released

Many points of information must be captured about each individual fish that is tagged and released for a study (Appendix F, Table F.1). These pieces of information describe the characteristics of the fish, the tags, and how the fish was handled, and when and where it was released to the environment. During analyses, these pieces of information will be used to differentiate groups of individuals for analysis and to evaluate whether certain individuals were more or less likely to survive.

3.1.3.2 Receiver Deployment Data

To identify and account for each unique deployment of a receiver, each data file containing tag code receptions will be associated with a unique identifier (NODE_ID) that identifies which node was deployed and when. Within the data set containing all tag detections, additional fields associated with NODE_ID describe the deployment in greater detail (Appendix F, Table F.2). These fields describe the location of the receiver and its position within a receiving array.

3.1.3.3 Detection Event Data

Receptions of JSATS tag codes within raw receiver data files are filtered to produce a data set of accepted tag detection events. Each detection event summarizes a series of individual detections that occur in the same place with only short temporal gaps between detections (Appendix F, Table F.3).

Stage 1: Filtering and Merging Raw Data to Detection Datasets

The tagging and release, autonomous receiver, and cabled hydrophone data sets will be subjected to QC checks, archived, filtered, reviewed in a second QC step, and merged to create a single set of accepted detection events (Figure 3.8). To produce accepted detection events, raw data are processed through a series of filters that remove detections arising from noise. Filter details are available in Appendix F.

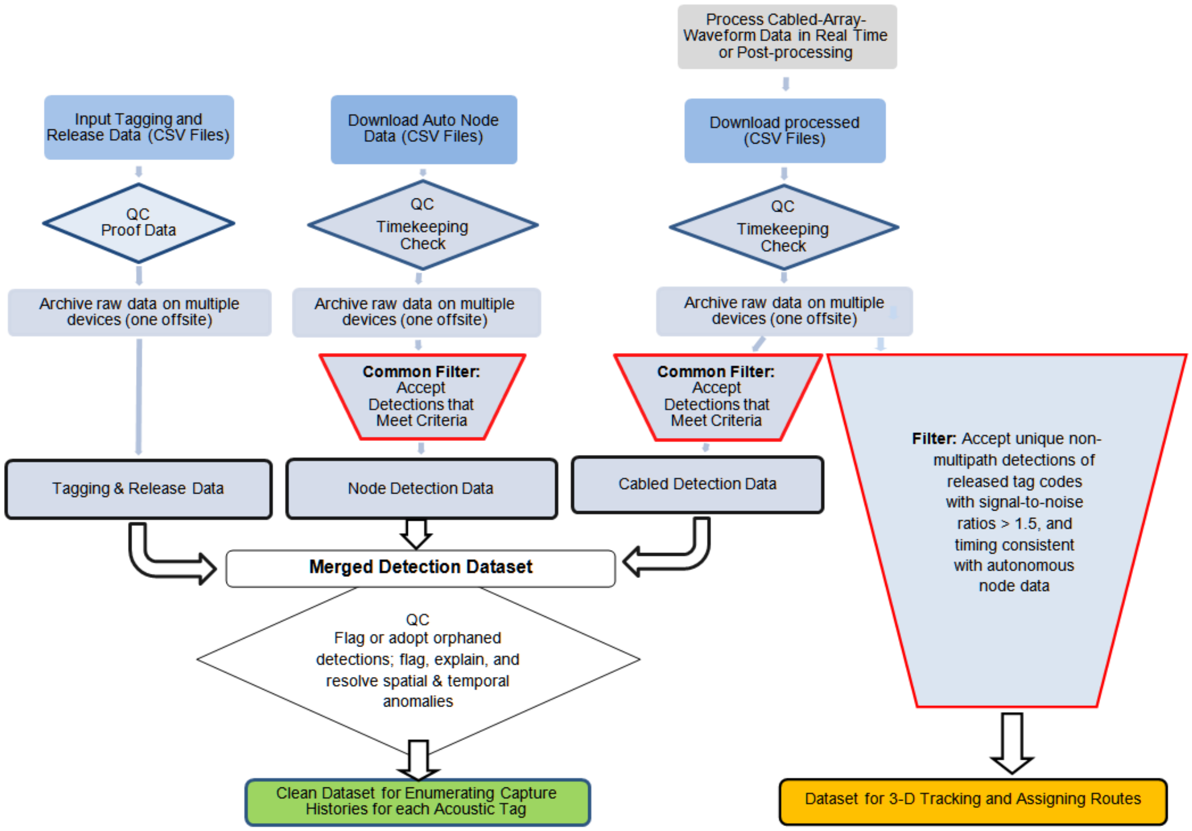


Figure 3.8. Diagram of Stage 1 data flow of clean data sets suitable for enumerating capture histories for every acoustic-tag (green box) or for 3D tracking of forebay movements, from acquisition through production. Data are used to assign routes of passage at dams. Steps to create the merged detection and 3D tracking data sets will be standardized in a single processing program developed by Dr. Skalski's team.

The output of the filtering process is a data set that summarizes accepted tag detections for all times and locations where hydrophones were operating. Each unique event record includes a basic set of fields that indicate the fish ID, the event first and last detection time, the location of detection, and the number of hits detected within the event. Additional fields capture specialized information, where available. An example is route of passage, which is assigned a value for the event that immediately precedes dam passage based on the spatial tracking of tagged fish movements to the location of last detection. Multiple receptions of messages within an event can be used to triangulate successive tag positions relative to hydrophone locations. Formats of variables in the clean cabled array data set are described in Appendix F, Table F.4.

The tagging and release data set and the detection data sets will be merged to create a clean detection data set (Appendix F, Table F.5). It will contain valid detection events for all detection locations. Each entry will be a single event for a unique single acoustic-tag observation and will contain all variables associated with tagging, release, and detection, including the receiver latitude, longitude, and depth. The clean detection data set can be used to check detection assumptions, capture histories, and travel times. However, the clean detection data set does not include all decoded receptions that could be useful for 3D tracking.

Creation of a cabled array data set suitable for 3D tracking and assignment of routes of passage at dams requires less stringent filtering than is used to create a detection data set, because tracking is an array-based exercise. Tag receptions that do not meet the criteria described above for identifying detections with very low risk of including false positives still may be useful for tracking. Tracking precision increases as number of time-synchronized hydrophones detecting a tag increases, regardless whether there are four hits within a specified time or in an acceptable temporal pattern on individual hydrophones.

Stage 2: Detection Data to Capture Histories

Capture histories summarize detection events by unique tag code and by array. Standardized software developed by Dr. John Skalski's staff will be used to create capture histories from the clean detection data. Such a capture history is particularly efficient for estimating survival and travel times, but is not intended to support more detailed examination of fish movement.

Stage 3: Capture Histories to Survival Estimates

The program Adjusted Tag-Life-Adjusted Survival (ATLAS) has been developed to estimate survival using the study design developed for AT studies. The capture histories described in the previous section act as inputs to ATLAS. In addition, data on tag-life must be incorporated to correct estimates if some tags are likely to expire during the study period.

3.1.3.4 Statistical Analysis

Statistical analysis will include comparison of the survival and behavior of fish that pass through different turbines (i.e., existing turbine, new fixed blade design, and new adjustable blade design). This analysis will be conducted by the University of Washington under a separate contract.

3.1.4 Quality Assurance/Quality Control

Quality assurance and quality control (QA/QC), along with surveillance of quality during the project, will be critical to successful implementation of the survival study. Besides standard QA/QC procedures, two of the main categories of QA/QC will be diagnostics and assumption testing. Fulfilling these QA/QC examinations will help ensure that the data are "bullet-proof." Additional features of the QA/QC plan are described in Appendix L of McMichael et al. 2011.

3.1.4.1 Standard Procedures and Elements

Numerous standard procedures and elements will be involved with QA/QC, many of which were explained previously in the context of implementation. Procedures will address the need to do the following:

- Develop, peer-review, and finalize the Experimental Design.
- Manage tag codespace.

- Optimize the design (specific 3D locations of hydrophones) for the dam-face and autonomous arrays.
- Perform detailed acceptance testing for procured equipment.
- Train personnel.
- Perform thorough system checks of telemetry equipment.
- Visit and inspect the entire data collection and analysis process.
- Document the percentage of fish tagged out of the total number handled; document the percentage of handling mortality.
- Control surgeon bias.
- Control for detection of dropped tags prior to release.
- Treat all releases the same as much as possible logistically.
- Archive fundamental data, including metadata, to support alternative or future analysis.
- Institute formal contractor version control and documentation for analysis software.

3.1.4.2 Data Diagnostics

Data diagnostics, along with assumption testing (described in the next section), will ensure that the data are ready for release to the CENWW. The diagnostic process will be structured and systematic. The results will be summarized and summaries will be reported to the USACE. Data diagnostics include the following topics: detection history fidelity, run timing, fish length frequency distribution, preliminary pseudo-real-time analysis, surgeon effects, preliminary calculations of survival estimates by various factors, and preliminary determination of the capture history data set by two independent groups. Some of these topics are discussed in the following sections.

Detection History Fidelity

Detection histories for individual fish reflect their movement and survival through various reaches of the study area. To ensure that the data quality is appropriate for survival modeling, these histories will be evaluated for apparent anomalies in the place and time of detection relative to release time or release location and in comparison to other times and places of detection. Detection events that are inconsistent with the release time or release location will be resolved by examining database entries on tag-release and node deployment. A sequence of detection events that suggests unreasonably rapid movement or movement across normally impassable barriers will be resolved by examining database entries on node deployments. Errors in information on node deployment or tag-release will likely affect multiple individuals, and those multiple lines of evidence will sometimes reveal a clear path to resolving the anomaly. Where no errors in node deployment or tag-release are found, it will be necessary to remove the event or events that are most likely anomalous to restore the fidelity of the detection history. The event or events with the fewest number of receptions relative to other events that create the spatial and/or temporal anomaly will have the greatest probability of occurring by chance, and will be removed.

In-Season Trial Analysis

Problems with data that are not evident in the field during collection can be revealed during data analysis. Therefore, it is important to perform trial analyses on data soon after data collection has commenced and periodically every 2 weeks thereafter. This diagnostic step can reveal anomalous or missing data and allow time for fixes to be implemented. It also provides analysts a jump-start on data analysis.

Preliminary Calculations of Survival Estimates by Various Factors

Preliminary calculations of survival estimates separately by release group, reach, release location, tag lot, etc. will be performed. The idea is to examine the survival results for abnormalities. For example, if fish released into the tailrace release pipe consistently had lower survivals than other release locations, it would suggest that there might be an issue of some kind and lead to an examination of the release procedures for that site.

Preliminary Determination of the Capture History Dataset by Two Independent Groups

While much effort is being devoted to standardizing data analysis methods, there is an element of decision-making and interpretation on the part of the analyst, especially during Stage 2 (Figure 3.9). After the raw data sets have been processed to produce the capture history data set (Stage 1 and 2; Figure 3.9), an independent review of all results will be performed. Any anomalies will be reconciled prior to commencing with the survival analysis (Stage 3; Figure 3.9).

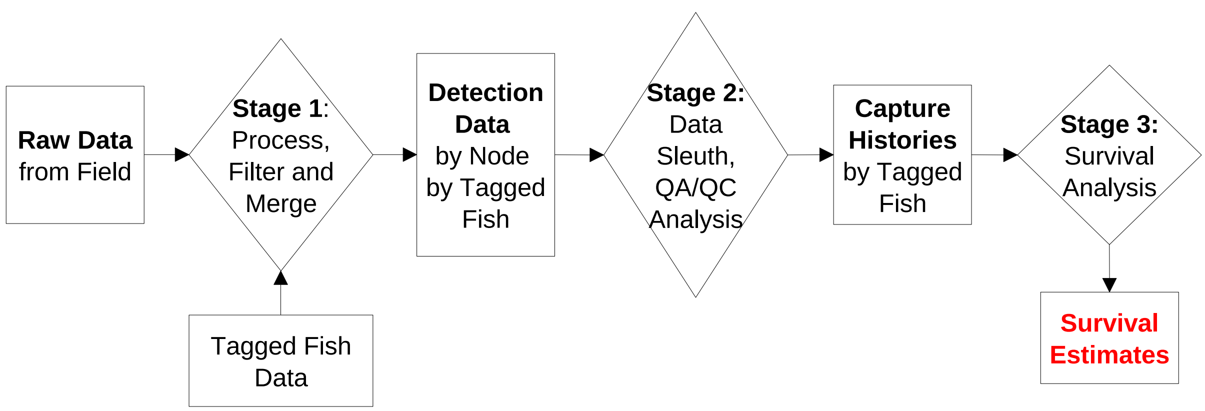


Figure 3.9. General data flow and analysis stage.

3.1.5 Reporting

Reporting will consist of in-season progress reports and annual reports, as described below.

3.1.5.1 In-Season Progress Reports

Bi-weekly in-season progress reports will be transmitted electronically from the contractor to the POC at the CENWW as well as to a distribution list established collaboratively by the CENWW POC and the contractor Principal Investigator. These progress reports will be delivered as Adobe Portable Document

Format (PDF) file attachments to an email and will begin 1 week prior to tagging and continue through the end of data collection. The purpose of these progress reports is to provide the CENWW with periodic summaries of accomplishments, planned activities, and issues. Each progress report will follow the format in the example below:

Example Only:

In-Season Progress Report No. 5
Ice Harbor Dam Performance Study

Report Date: May 29, 2017

Prepared for: U.S. Army Corps of Engineers, Walla Walla District

Prepared by: Pacific Northwest National Laboratory

Introduction: This is the fifth in a series of bi-weekly, in-season progress reports on the conduct of the AT survival study during 2017. This report is intended to provide the Walla Walla District with periodic summaries of accomplishments, planned activities, and issues for the AT study encompassing fish passage and survival metrics at Ice Harbor Dam.

	April				May					June				July					August	
Week beginning	3	10	17	24	1	8	15	22	29	5	12	19	26	3	10	17	24	31	7	14
Progress report	X		X		X		X		X		X		X			X		X		X

Accomplishments and Plans:

	Accomplishments	Planned Activities	Issues
Time Period	**5/16 to 5/30/17**	**5/31 to 6/11/17**	
Safety			
Fish tagging and release			
Cabled arrays			
Autonomous arrays			
Data analysis			
Reporting			

Schedule: Items shaded gray are completed

Summary		**Due Date to KH**	
Final Databases	**Responsible Staff**	**Spring**	**Summer**
Hydrophone locations	JS (cabled), ST (autonode)	15-Jun	15-Jun
Tag-Release	KD	10-Jun	10-Aug
Tag-Life	DD	5-Jun	10-Aug
Event Data	KH (auto), DD (cabled)	10-Jul	10-Sep
Format, FINAL QA/QC, Deliver to Skalski	KH	15-Jul	15-Sep
Passage (for SPE)	DD	15-Aug	25-Oct

Spring Fish Tagging and Release	Due Date	Staff
SP 1st fish release	22-Apr	EA, KD
SP last fish release	25-May	EA, KD
SP QC'd tag and release data	weekly	KD, CV
SP tagging and release database	10-Jun	CV, KH

Summer Fish Tagging and Release	Due Date	Staff
SU 1st fish release	1-Jun	EA, KD
SU last fish release	9-Jul	EA, KD
SU QC'd tag and release data	weekly	KD, CV
SU tagging and release database	10-Aug	CV, KH

Spring Autonode Array Data	Due Date	Staff
SP IHR AR deployment	20-Apr	ST
SP IHR AR servicing complete	25-Jun	ST
SP IHR AR datasheet backup (PDF)	27-Jun	KH
SP IHR AR metadata entry	27-Jun	KH
SP IHR AR processing	30-Jun	KH
SP IHR AR QC'd raw database	3-Jul	KH
SP IHR AR filter and QC -(RCH)	10-Jul	RH, KH
SP IHR AR filter and QC	10-Jul	KH
SP IHR AR QA/QC comparison	12-Jul	KH
SP final detection and event data	15-Jul	KH

Spring Cabled Array Data	Due Date	Staff
SP IHR CA deployment	10-Apr	JS, ST
SP IHR CA hydrophone locations	15-Jun	JS
SP IHR CA data collection complete	25-Jun	JS, RH
SP IHR CA data download complete	25-Jun	JS, RH
SP IHR CA datasheet backup (PDF)	26-Jun	JS, RH
SP IHR CA data backup	27-Jun	JS, RH
SP IHR CA post-acquisition decoding	30-Jun	JS, DD
SP IHR CA gap check	30-Jun	JS, JM
SP IHR CA data blocks to lead engineer	1-Jul	JM
SP IHR CA data filtering (2+ methods)	10-Jul	DD
SP IHR CA QA/QC comparison	10-Jul	DD, KH, RH
SP IHR CA event data	15-Jul	DD to KH
Passage Data (for SPE)	15-Aug	DD

3.1.5.2 Annual Reports

The annual reports will provide delivery of the results from each year of testing. The outline for the annual report is provided below (Figure 3.10). Draft annual reports will be due on December 15 of the year of study, with the final due on February 15 in the year following the study.

<u>Example Acoustic Telemetry Report Outline</u>

I. Title
II. Preface
III. Executive Summary
   a. Study Objectives
   b. Survival Models
   c. Results
IV. Table of Contents
V. Table of Tables
VI. Table of Figures
VII. Introduction
   a. Study Objectives
VIII. Methods
   a. Release-Recapture Design
   b. Handling and Tagging Procedures
   c. Statistical Methods
   d. Tests of Assumptions
IX. Results
   a. Environmental Conditions
   b. Handling Mortality and Tag Shedding
   c. Estimates of Passage Survival
   d. Travel Time Estimates
   e. Tailrace Behavior
X. Discussion
XI. Literature Cited

Figure 3.10. Example annual report outline.

3.2 Characterization of the Turbine Passage Environment

3.2.1 Preparation

The main categories of preparation are equipment, procurements, personnel and logistics, training, and deployment. Preparation will be complete when all equipment hardware and software have been finalized, all procurements have been received and accepted, all personnel have been designated and logistics completed, all SF have been tested and certified as being ready to collect data. Plans for the SF injection system will be designed, approved, and constructed and all needed equipment will be acquired.

3.2.1.1 Equipment

Sensor Fish (SF) will be used to characterize the turbine passage environment for CENWW at IHR. Equipment will consist of SF, the SF injection system, and SF recovery materials. To describe the system in brief, SF are prepared and activated on the intake deck, then, released down into the turbine intake through the injection system, finally, each SF is recovered in the tailrace river environment with two or more boats and the data is recovered from each SF.

Sensor Fish

The current SF (Generation 2) is approximately 24.5 mm in diameter, 90.3 mm in length, and weighs ~42 grams–similar to a yearling salmon smolt–and is nearly neutrally buoyant in fresh water. The polycarbonate casing contains angular and linear accelerometers that collect data to describe motions with 6 degrees of freedom, as well as a pressure sensor, temperature sensor, and magnetometer transducer. The digital sampling frequency of the SF is 2,048 Hz for all sensors, collecting 2048 sample points per second on each transducer. Sensor output is digitized and stored in a nonvolatile memory and downloaded into a computer following recovery of the sensor. The pressure, acceleration, and rotation time histories provide a detailed record of the SF response to hydraulic and mechanical forces during passage through the fish passage route.

Pressure

The pressure sensor (MS5412-BM, Measurement Specialties, Inc., Hampton, VA, USA) on the flexible board consists of a micro-machined silicon pressure sensor die mounted on a 6.2 x 6.4 mm ceramic carrier; it has a full-scale range of 12 bar (174 psia). The overpressure rating is 30 bar (435 psia).

Acceleration

The primary accelerometer (ADXL377, Analog Devices, Inc., Norwood, MA, USA) is a chip-scale package, low power, three-axis analog component with a typical full-scale range of ±200 g per axis and a 10,000 g shock survival overload rating. The accelerometer also has user-selectable bandwidths to suit different applications, with a range of 0.5 Hz to 1300 Hz for the x-axis and y-axis and a range of 0.5 Hz to 1000 Hz for the z-axis. It is placed at the center of the circuit board, which coincides with the center of mass of the device, for the greatest accuracy.

Rotation

The gyroscope (ITG-3200, InvenSense, Inc., San Jose, California, USA) is a digital-output three-axis microelectromechanical systems component with a full-scale range of ±2000°/s per axis. The ITG-3200 includes three 16-bit analog-to-digital converters, which are used to digitize the gyroscope outputs. It includes a user-selectable internal low-pass filter bandwidth and an inter-integrated circuit (I^2C) interface. The initial zero-rate output is ±40°/s, and the linear acceleration sensitivity is 0.1°/s·g. The gyroscope also includes an embedded temperature sensor. The gyroscope is mounted near the center of the circuit board, close to the accelerometer.

Magnetometer

The eCompass module (LSM303DLHC, STMicroelectronics, Geneva, Switzerland) integrates a three-axis digital accelerometer and a three-axis digital magnetometer in the same package. The accelerometer has a maximum full-scale range of up to ±16 g, and thus is not suitable for collecting data during the most intense part of the passage (e.g., collision with structures), but it can improve the precision of the remaining data. The magnetometer has a selectable full-scale range of up to ±8.1 gauss. As with the gyroscope, this component supports an I^2C serial bus interface and has an on-board temperature sensor.

Temperature

The primary temperature sensor (TC1046, Microchip Technology Inc., Chandler, AZ, USA) on the flexible board is also an analog component with linear temperature slope of 6.25 mV/°C and a full-scale range of −40 to +125°C. The temperature sensor is mounted close to the pressure sensor, with the intervening space covered with heat-conductive epoxy (Omega Bond 200, OMEGA Engineering) to improve the thermal contact between the temperature sensor and the metal enclosure of the pressure sensor, which comes into direct contact with the water.

Recovery Module

The recovery module includes a download board and a program board, each located at one end of the SF. The download board allows users to download serial data from the SF and recharge the battery, and the program board allows users to update the microcontroller firmware. Both boards contain a nichrome wire used for the recovery mechanism, which consists of a spring-loaded weight tied down with a piece of fishing line that loops over the nichrome wire. The microcontroller briefly applies a large current to the nichrome wire, which heats up the wire, severs the fishing line, and releases the weight on the end. The process is then repeated for the opposite end of the SF. The SF then rises to the surface as the balloon inflates. A radio-frequency transmitter and four high-intensity orange light-emitting diodes (LEDs) are activated periodically so that users can locate the device. The carrier frequency of the radio frequency pulse is 146 MHz for compatibility with existing receiver equipment, and can be disabled if external radio transmitters are to be used. The LEDs face outward to permit good visibility in most orientations, and the color was chosen to provide good contrast with water.

Sensor Fish Injection System

The SF injection system will be comprised of an injection junction (fittings and valves) used to control water flow and SF releases through reinforced flex hose that is secured to the top of or inside a SS metal pipe. Three (3) SS injection pipes will be attached to two support frames of the submerged traveling screen (STS), with the terminus of the pipe(s) at elevations within the powerhouse test unit provided by CENWW staff. The pipe terminus will have a sweep elbow to ensure the fish are introduced at the desired depth and orientation to the intake flows, precluding shear forces from the flow convergence. All pipes will have smooth joint transitions, to minimize turbulence and impediments within the pipe system. All parts of the pipe shall be made from SS material, including all fasteners. In addition, water will need to be injected into the flex hose at a flow rate similar to water velocities found at the terminus of each pipe in order to flush each SF through each pipe.

Injection Pipes

Two schedule 40 SS 4.0-in diameter injection pipes will be needed for each of the 327 ft and 337 ft elevations. One schedule 160 SS 4-in diameter injection pipe will be needed for the 314.5-ft elevation test. All three injection pipes will be mounted to two 12.5-in diameter horizontal structure pipes that are a part of the STS frame (Figure 3.11) using custom U-bolts made from SS (Figure 3.15; Appendix G, Figures G.1 - G.3) and the following upper bracket design. The distance between the upper and lower horizontal structure pipes of the STS frame is14 ft.-10 in., center to center. The upper bracket plate is 9.5 in x 18.0 in, made from .375-in SS plate, and attached to the 4.0-in injection pipe using SS pipe clamps with SS hardware. This allows the upper mount to slip up or down in case the distance between the upper and lower bracket plates are off. The lower bracket plate for the 327 ft and 337 ft elevation injection pipes are also 9.5 in x 18.0 in and made from .375 in SS plate. This bracket plate should be permanently attached to the 4.0-in injection pipe using a smaller .3125-in thick plate on each side of the injection pipe (Appendix G, Figure G.2). This plate should be fixed, welded to the injection pipe and lower bracket. The lower bracket on the 337-ft elevation injection pipe is similar except it shall be 12.0 in. wide with the bracket welded to two 2.0-in SS pipes that extend the injection pipe to the lower 12.5-in diameter horizontal structure pipes of the STS frame (Appendix G, Figure G.3). This bracket plate should be fixed with welds as described for the 314.5-ft and 327-ft elevation lower bracket. U-bolt holes in both upper and lowers brackets should be sized 0.25 in larger than the diameter of the U-bolt size used to allow for some tolerance in the bend length.

Figure 3.11. STS supported by the gantry crane and a 4-in. diameter SS fish injection pipe is supported by a mobile crane. SF injection pipe is secured to the STS frame lower 12.5-in. horizontal pipe via a bracket and U-bolt hardware system.

The 314.5-ft elevation injection pipe (Appendix G, Figure G.1) shall be 42 ft long. If two pieces of pipe are needed to create one 42-ft long pipe, the weld joint shall be above the lower bracket plate. The type of weld shall be a Complete Joint Penetration (CJP) weld created using Gas Tungsten Arc Welding (GTAW) according to the procedures specified by ASME IX.

The 327-ft elevation injection pipe shall be 32-ft long (Appendix G, Figure G.2). The 337-ft elevation injection pipe (Appendix G, Figure G.3) should be built to be 19.5-ft long to the center of the pipe exit. A 337-ft release elevation puts the pipe exit above the lower 12.5-in diameter horizontal structure pipe of the STS frame. Securing the bottom of the injection pipe to the lower horizontal structure pipe of the STS frame will require a 6.0-ft long extension welded to the bottom of the injection pipe (Figure 3.12). The extension shall be constructed from two schedule 40 2.0-in SS pipe. The 2.0-in extension pipes will be welded to the injection pipe.

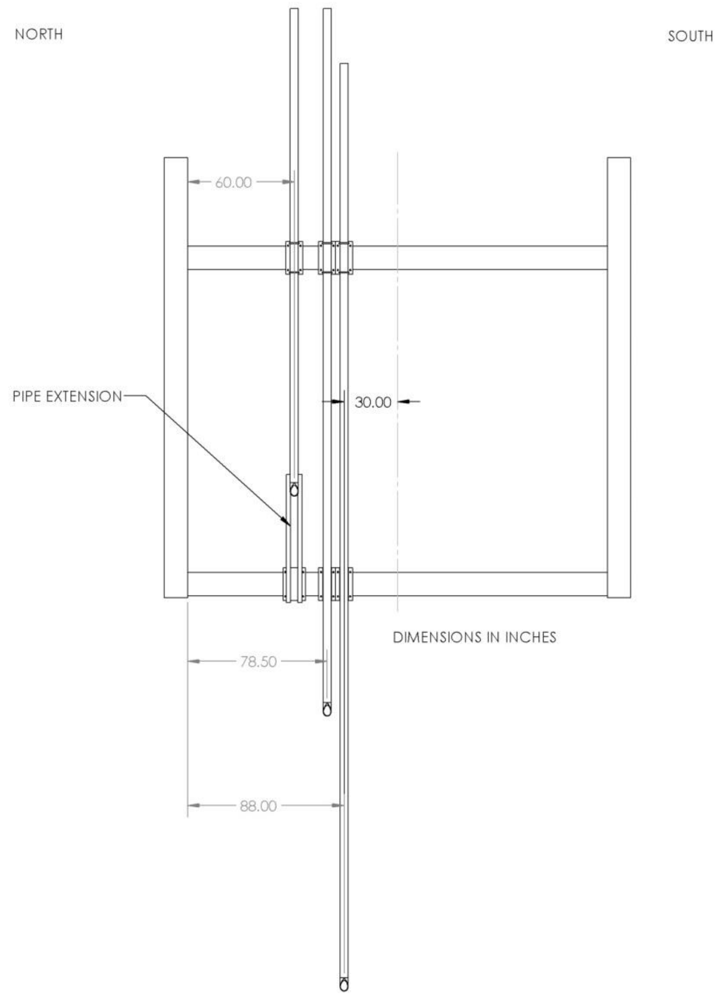


Figure 3.12. Proposed locations of the three injection pipes attached to an IHR STS.

Flex Hose and Fittings

Reinforced flex hose is required in order to extend the injection system from the top of each injection pipe, fixed to the STS, up to the powerhouse intake deck. At least 100-ft of 4.0-in diameter reinforced flex hose is needed for both the 327-ft and 337-ft elevation injection pipes. In addition, at minimum, 150 ft. of 2.5-in diameter reinforced flex hose is needed for the 314.5-ft elevation injection pipe. A combination of PVC and brass fittings and valves will be needed to build the injection junction (Figure 3.13) and injection tank (Figure 3.14) systems. The injection junction apparatus allows control over water flow and the injection tank is used to flush the SF into the flex hose and fixed SS pipes. A comprehensive list of equipment can be found in Appendix B, Table B.2.

Figure 3.13. SF injection pipe top bracket plate is shown secured to the top STS frame horizontal pipe via SS U-bolt, pipe clamp, and hardware.

Figure 3.14. Holding tank for fish injection system.

Additional equipment to consider:

- Union for 4-in and 2.5-in flex hose
- 5-in and 3-in diameter hose clamps
- Pipe clamp set for each 4-in diameter flex hose
- Quick connect fittings for 4-in and 2.5-in diameter hose and PVC pipe
- Various size PVC reducer fittings
- Minimum .25-in diameter SS wire rope (flex hose support) and associated hardware. 150 ft. per injection pipe.

Water Pump

Water is needed to flush each SF down through all three injection pipes. Water source locations include either the powerhouse forebay or a STS gatewell slot near the test location. Vertical distance from the intake deck to the forebay water surface elevation is approximately 20.0 ft.; forebay water surface elevation can vary daily. A water pump is required with enough power to lift water from the forebay or gatewell and provide enough water force so that water entering the injection pipe attempts to match the water velocity that the test unit experiences at each test elevation (Figure 2.4). A submersible centrifugal pump with the following specifications is proposed for moving water in a confined area.

- 5.0HP, 230/460V, three-phase, electric motor
- 3” (NPT) female discharge port
- 50’ of molded power cord with strain relief

A powerful, versatile, and low maintenance electric pump is recommended that is works for a wide range of operations. This type of pump requires a control box to provide safe operations and safety shutdowns such as thermal & voltage overload protection. A pump this size may require a lifting apparatus in order to lower and raise it from the water.

Sensor Fish Recovery Materials

A minimum of two (2) boats are required to support SF recovery efforts in the IHR tailrace. The contractor shall coordinate with IHR staff to determine equipment, boat, and motor size requirements, and boat restricted zone (BRZ) access (Appendix H) and permitting requirements for operating in the tailrace. Additional equipment recommended to support SF recovery is listed in Appendix B, Table B.2.

Inventory

Inventory for all tracked SF equipment with a value greater than $300 and not considered expendable will be monitored by CENWW using barcode readers and a common database. The contractor’s inventory database will correspond to the CENWW’s database. When not in use, each piece of equipment will be assigned a storage location that will be updated throughout the season as maintenance issues arise and equipment is replaced or repaired. The inventory will be provided to the CENWW POC annually.

3.2.1.2 Procurements

Procurement needs will be communicated to the CENWW POC. Unless noted otherwise, contractor-procured shipments will be delivered to the contractor. The responsible receiving party will enter the procurement into a formal receipt log. Procurements will not be documented as complete until the product or tool has been tested and confirmed to be ready for use in the study. Close coordination with CENWW staff will be required as the testing schedule and IHR project support schedule will affect timing of when equipment should be ready (e.g., installation of injection pipes on the STS). All equipment will need to be procured far in advanced to meet these schedules. A comprehensive list of equipment that must be procured can be found in Appendix B, Table B.2.

Sensor Fish

The SF used in this study will be manufactured by the vendor selected by CENWW. All SF must be received prior to the start of a turbine passage environment characterization study. A comprehensive list of equipment that must be procured can be found in Appendix B, Table B.2. This list does not include spare parts (except for SF and radio tags; ~5% loss rate) and assumes 1000 releases.

Radio Telemetry Equipment

A variety of radio telemetry equipment is available off-the-shelf and shall be procured in advance of a turbine passage environment characterization study. Radio receivers, transmitters, and antennas all shall be purchased in the frequency range of 164 to 168 MHz. Radio telemetry equipment (radio transmitters, receivers, antennas) has been purchased from ATS (Insanti, Minnesota); however, the vendor equipment will be re-evaluated by CENWW and the contractor prior to future purchases. The CENWW also owns multiple radio receivers in the 164 to 168 MHz range that can be used if available.

Sensor Fish Injection System

Injection pipes will be procured directly by the contractor. All engineering drawings must be approved by CENWW prior to purchase. All other components of the injection system are off-the-shelf elements. All equipment in Appendix B (Table B.2) will need to be procured as to specifications noted.

Acceptance Testing

Prior to deployment in the field environment, all SF will be certified for field use and calibrated to specifications within a controlled laboratory setting. Calibration and testing will ensure the SF are capable of recording rapid and extreme variations in angular acceleration and pressure needed to capture the conditions encountered in a turbine environment. Each SF will be assigned a unique identification (ID) for data verification and assessment. All the sensors, including the pressure sensor, three-axis accelerometer, three-axis gyroscope, three-axis orientation sensor, and temperature sensor will be calibrated and evaluated individually before and after assembly in the lab.

Pressure

Before pressure sensors are mounted on the SF housing, they will be calibrated using a HOBO® U20-001-02 water level logger (Onset Computer Corporation, Bourne, MA, USA) in a pressure chamber. The pressure sensor in the HOBO logger has a full-scale measurement range of 160 psi, with accuracy ±0.05%. The pressure of the chamber should be tested at five different values for specific times.

After the complete SF device is built, its pressure sensor measurement will be evaluated by placing the SF in a rapid-decompression testing chamber (hyperbaric chamber). The chamber will be programmed to simulate the pressure–time history of a passage through a hydro turbine, with pressure range and rate of change representative of turbine passage. The pressure data acquired by the SF during the test will be compared to the pressure data measured by another pressure sensor (Honeywell TJE Pressure Transducer with 200 psia range and 0.10 % accuracy) built into the hyperbaric chamber. The relative error of pressure measurement should be less than 2%.

Acceleration

Before final assembly, the acceleration measurement of the SF will be calibrated on a linear acceleration test track with a tri-axial constant-current line drive accelerometer (Brüel & Kjær Sound & Vibration Measurement A/S, Nærum, Denmark; B&K) and a data acquisition card (Model PXIe-6124, National Instruments, Austin, TX, USA) (NI) housed in a PXIe-1073 chassis. The NI data acquisition card has a 16-bit analog-to-digital converter (analog input), each with a maximum sampling frequency of

4 MHz. The SF will be mounted on a test track aligned with one of the axes, along with the B&K accelerometer, for each acceleration test. Each axis output of the B&K accelerometer will be connected to one of the three PXIe-6124 analog inputs. The data acquisition card should be controlled by a MATLAB program written specifically for these tests. The SF mounting plate will be pulled from a selected distance to collide with a stopper. After accelerating following release, the impact with the stopper causes the SF to experience a high-magnitude impulsive acceleration event. The other two axes will be calibrated using the same methods. After final assembly, the acceleration of each axis will be evaluated again using the same test fixture as part of the acceptance testing. The relative errors of linear acceleration measurements should be less than 5%.

Rotation

The 3D rotational velocity measurement of the SF will be calibrated in a rotation test fixture with high-speed videography. Each of the three axes is calibrated individually by mounting the SF in the fixture with one axis parallel to the rotational axis of the fixture. The rotational movement is also recorded using a digital high-speed camera (Photron PCI FastCAM 1280; Photron USA, Inc., San Diego, California) equipped with a 50 mm lens. The camera is capable of a frame rate of 500 frames per second at a resolution of 1,280 x 1,024 pixels, and up to 16,000 frames per second at a reduced resolution. Trajectories of the SF will be obtained using a motion-tracking software package (Visual Fusion 4.2; Boeing-SVS Inc., Albuquerque, New Mexico). The calibration and evaluation will be conducted in two modes: variable and stationary rotation. In the variable rotation mode, the rotational velocity of the fixture should be controlled to alternate between ±150, ±500, ±1500, and ±2000°/s. In the stationary rotation mode, each axis of the gyroscope will be evaluated again using the same rotation test fixture at five different constant speeds (both clockwise and counterclockwise). The relative error of rotational velocity measurements should be less than 5% by comparing the sensor measurements with the results of the motion analysis using high-speed videos.

Magnetometer

The magnetometer (electronic compass) should be calibrated using the same rotation test fixture used for calibration of the gyroscope. The sensor will be placed in the fixture with one axis parallel to the rotational axis of the fixture. The speed of the rotation fixture was set at a constant slow speed of 150°/s for a minimum of 360° to get rotation through a full 2D plane. The performance of the electronic compass was checked by placing the SF on a leveled anti-static mat and aligning the x-axis to the local magnetic north direction. The accuracy of the heading output of the electronic compass was determined to be within ±4°.

Temperature

The primary temperature sensor was calibrated in ice water with a DT8852 digital thermocouple thermometer (General Tools and Instruments, New York, NY). The thermometer has a full-scale range of −200° to +1370°C, with 0.1% accuracy and 1 second response time. Mixed crushed ice and deionized water were added to a clean beaker to form a watery slush. The SF was submerged in ice water for 20 minutes before starting data collection. The ice water temperature was recorded by the DT8852. Extra care was taken to not let the SF or the probe of the DT8852 contact the beaker. The temperature sensor was also evaluated at room temperature by comparing with the DT8852 reading. The difference between the SF measurement and the DT8852 for both tests was less than ±2°C.

3.2.1.3 Personnel and Logistics

This section details the labor plan for all SF data collection and analysis outlined in this IP. The staff required to complete all tasks will be coordinated by the contractor. The contractor may also work with subcontractors to fill some roles.

Labor Plan for Data Collection and Analysis

The number of personnel required for the completion of each task is listed in Table 3.8. The number of individuals required to complete the tasks outlined in the schedule may vary depending on the abilities and commitments of personnel involved.

Table 3.8. Number of individuals at each position level needed to complete each task. This number may vary contingent on personnel's abilities and commitments. All personnel are required to participate in at least one activity within a given task.

Task	Timeline	Specific Activities	Position	Number of individuals required
1-Attend Pre-Work Meetings/Management	6/1/XX-6/30/XX+1	a) Coordinate activities with CENWW district staff b) Coordinate activities with IHR project staff c) Finalize experimental design	Chief Scientist	1
			Senior Biometrician	1
			Senior Biological Scientist	1
			Biological Scientist	1
2-Preseason/Planning	6/1/XX-9/30/XX	a) Procure equipment and supplies b) Acceptance testing of equipment c) Training of personnel d) Staff/equipment planning e) Set-up subcontracts f) Deployment coordination g) Site visits	Chief Scientist	1
			Senior Biometrician	1
			Senior Biological Scientist	1
			Biological Scientist	2
			Fisheries Biologist	0
			Biological Science Technician	4
3-Deployment/Demobilization	8/1/XX-9/30/XX	a) Deployment coordination b) Deploy/test fish injection system c) Demobilize fish injection system	Biological Scientist	2
			Biological Science Technician	2

Table 3.8. (contd)

Task	Timeline	Specific Activities	Position	Number of individuals required
4-Sensor Fish Releases	9/1/XX-11/30/XX+1	a) Daily operations coordination b) Staff/Equipment planning c) Release/recover Sensor Fish	Senior Biological Scientist	1
			Biological Scientist	3
			Biological Science Technician	4
5-Data Collection/Processing	9/1/XX-6/30/XX+1	a) Archive data b) Process data c) Data diagnostics d) Statistical analysis	Chief Scientist	1
			Senior Biometrician	1
			Biological Scientist	2
			Biological Science Technician	2
6-Prepare Deliverables	9/1/XX-6/30/XX+1	a) Prepare preliminary reports b) Prepare annual report	Chief Scientist	1
			Senior Biometrician	1
			Biological Scientist	2
			Biological Science Technician	2

3.2.1.4 Training

Staff assigned to deploy and recover the SF in the field environment will be experienced and knowledgeable concerning the operation of SF, as well as in data acquisition, download, interpretation, boat operations, and operation of radio telemetry equipment. This training will be provided by experienced staff members prior to data collection and may occur through reading assignments, discussion, watching videos, observation by trainees of tasks being performed, immediate supervision of trainee performing task and if/when deemed appropriate by trainer, the trainee may perform the task independently.

Sensor Fish Injections

Training activities related to the preparation and injections of SF include:

- Tying the Tungsten weights onto the recovery circuit boards
- Attaching balloon tags to the SF end caps
- Using the SF software, SFCommunicator, to configure the SF for a release
- Deploying the SF using the release system

- Using the SF software, SFCommunicator, to download and convert the data

All staff who will work on the powerhouse intake deck releasing SF will complete this training. Training for all activities will take place at the contractor's facility and will be supervised by experienced staff members.

Sensor Fish Recovery

Training activities related to the preparation and operation of radio telemetry equipment:

- Use of radio telemetry receivers
- Methods for identifying the locations of radio-tagged SF
- Boat operations in the tailwater environment that meet the contractors and CENWW requirements

All staff who will work on the powerhouse intake deck releasing SF and in each SF recovery boat will complete this training. Training for all activities will take place outdoors or at IHR.

3.2.1.5 Deployment

This section details the deployment procedure for all equipment to be installed or located at or near the IHR powerhouse to support the characterization of the turbine passage environment. The lateral location(s) and position(s) of fish release pipes will be determined by CENWW staff prior to the initiation of the study and communicated to the study contractor. Release locations will be determined and verified through physical hydraulic model investigations at ERDC 1:25 scale model of Ice Harbor turbine, located in Vicksburg, Mississippi, prior to beginning of the field evaluation. Additional injection system equipment location will be dictated primarily by the study location on the dam. A CENWW crane, operator, and riggers to install and remove the injection pipes and receiving electronic project operation data for the test turbine unit in 5-minutes increments will need to be directly coordinated with CENWW, if necessary.

Injection System

It is recommended that the injection pipes be stored horizontally on the intake deck near the test unit in advance of injection pipe installation to allow time to prepare the pipes for installation and add accessory equipment or sensors to the pipe as needed. For injection pipe installation, it is also recommended to use one mobile crane to lift and vertically support all three injection pipes individually and use one IHR gantry crane to lift and support the STS. This technique requires that the mobile crane work directly under the gantry crane. Lifting straps are recommended for use with the mobile crane and one pipe clamp attached near the top end of the pipe can be used to support the lifting strap. Depending on the size of mobile crane, there may not be enough head clearance under the gantry crane to lift the 314.5-ft elevation injection pipe high enough for it to clear the gatewell slot safety hand rail. In this case, due to the length of the pipe and position of the gantry crane, the 314.5-ft elevation injection pipe will need to be set inside the STS gatewell slot in advance of moving the STS into position for pipe installation.

The 314.5-ft and 327-ft elevation injection pipes will be mounted side-by-side as close to the centerline as allowed by the STS tilt mechanism. A single injection pipe installed for a previous study was positioned 30-in. north from the STS centerline (Normandeau Associates et al. 2008). The 337-ft elevation injection pipe shall be mounted approximately 5 ft. from the north side of the STS screen frame (Figure 3.15).

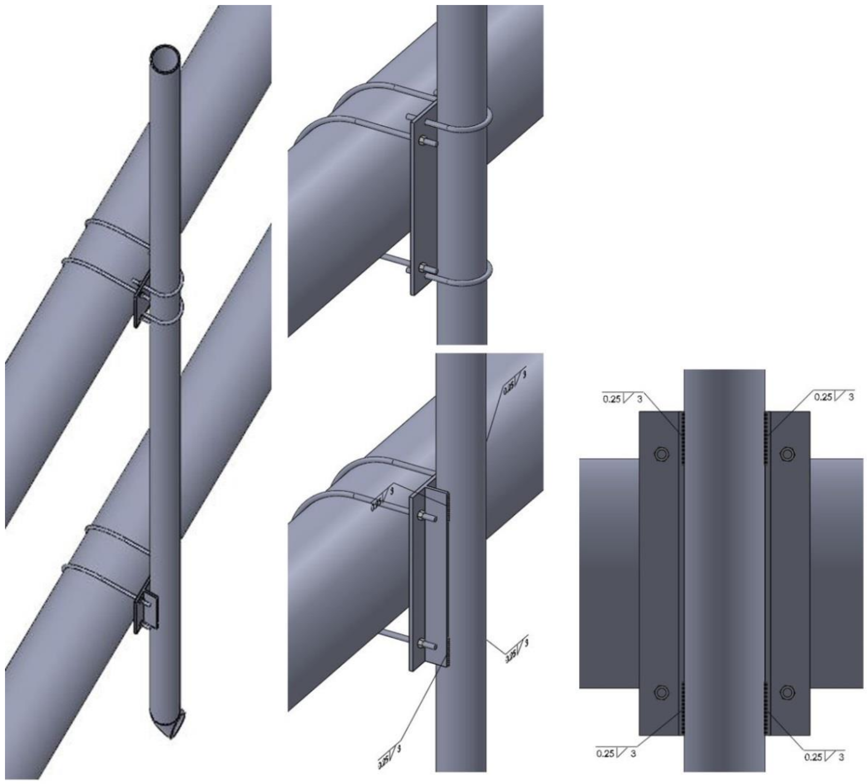


Figure 3.15. Concept drawings of the SF release pipe and associated hardware.

The following steps are recommended for installing the injection pipes described in Section 3.2.1.1:

A. For the 314.5-ft elevation injection pipe only, insert a 150-ft section of 2.5-in diameter reinforced flex hose into the injection pipe, working the top of the pipe until the end of the flex hose meets the bottom of the injection pipe. Secure the flex hose to the injection pipe so that the flex hose is rigid, without vertical movement.

B. Gantry crane lifts the STS until the bottom horizontal frame support pipe is above the top of the safety hand rail, and hold the STS in this position.

C. Mobile crane will lift the injection pipe vertically and lower it into the gatewell slot along the downstream side of the STS until the bottom injection pipe bracket plate is at the same height as the STS bottom horizontal frame pipe (Figure 3.11).

D. Secure the bottom injection pipe bracket plate to the STS bottom horizontal frame pipe with U-bolts and fasteners (Figure 3.11).

E. The mobile crane can relax its strain on the injection pipe at this time. Gantry crane will lower the STS until its top horizontal frame pipe is just above the top of the safety hand rail and hold (Figure 3.13). The mobile crane will lower its boom as the gantry crane lowers the STS.

F. Remove lifting strap from injection pipe.

G. Secure the top injection pipe bracket plate to the STS top horizontal frame pipe and injection pipe with U-bolts, pipe clamps, and fasteners (Figure 3.13).

H. For the 327-ft and 337-ft elevation injection pipes only, secure a 100-ft section of reinforced 4.0-in flex hose to top of the injection pipe via hose and pipe clamps, and duct tape (Figure 3.16).

I. Secure approximately 150-ft of .25-in diameter SS wire rope to an eye bolt welded to the top of the injection pipe (Figure 3.16).

J. Secure approximately 100-ft of the 4.0-in diameter reinforced flex hose to the wire rope via hose clamps and duct tape (Figure 3.17). If sensors were attached to the injection pipe, sensor cable can be secured to the flex hose or wire rope at this time as well.

K. Support the flex hose at the top of the STS gatewell by securing the SS wire rope and flex hose to the gatewell slot safety hand rail.

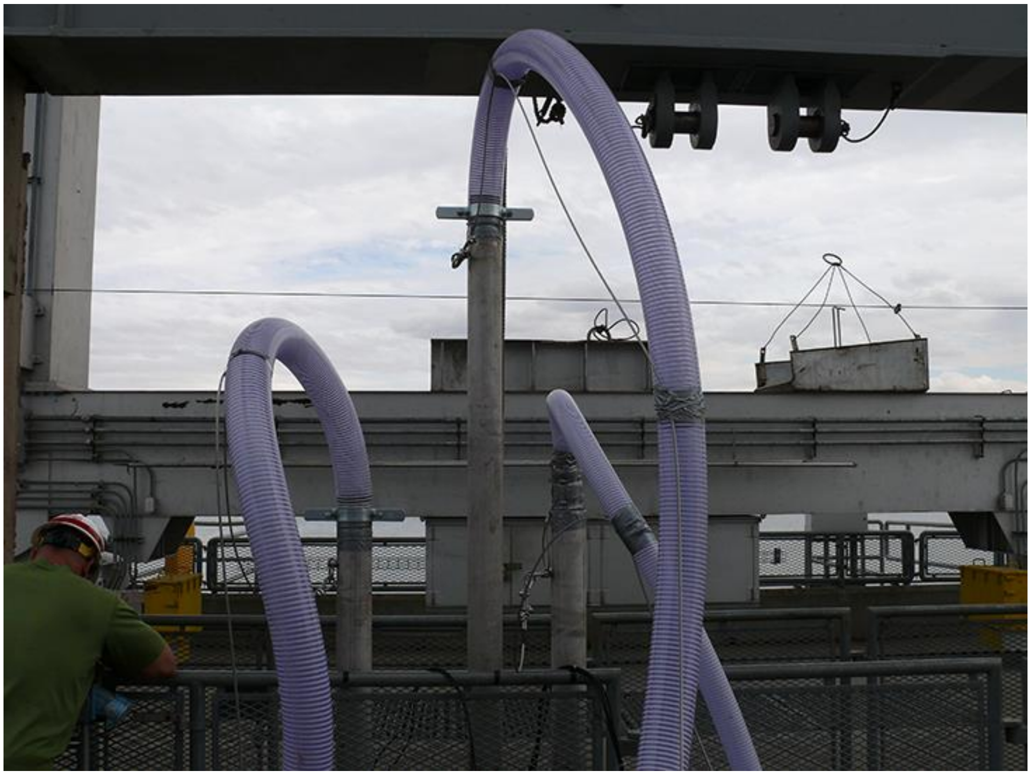


Figure 3.16. The STS lowered into the gatewell revealing the reinforced flex hose connected to the top of three SS injection pipes.

Figure 3.17. Four-inch-diameter flex hose is shown secured to .25-inch-diameter SS wire rope via hose clamps and duct tape.

At this point or at some time in advance of conducting treatment tests, the injection junction and injection tank systems used to control water flow and SF released into the reinforced flex hose can be assembled and attached to the end of either the 4.0-in or 2.5-in diameter flex hose as shown in Figure 3.18. Downstream of the injection junction, use of an injection tank (Figure 3.14) is recommended to flush SF down through the flex hose and injection pipe. A tank injection system will help prevent air pockets (bubbles) from entering the injection system.

If a water pump is used for the water source, deploy the water pump (see water pump specification in Section 3.2.1.1) in the forebay or a STS gatewell slot near the test location. If the forebay is used to extract water, appropriate steps will need to be taken to protect all hoses from frequent intake deck traffic between the forebay and STS gatewell slot.

Additional flex hose and fittings in various sizes will need to be added to the water pump in order to reach and pressurize water flow to the SF injection system. The size and configuration of these fittings is dependent on the velocity of water needed at the point of injection (i.e., reduced diameter fittings and hose can increase water pressure). If using an electric water pump, power cable length from the pump will need to be long enough to reach nearby power outlets. In addition, water pump power cable connecters need to match nearby power source outlets on the dam.

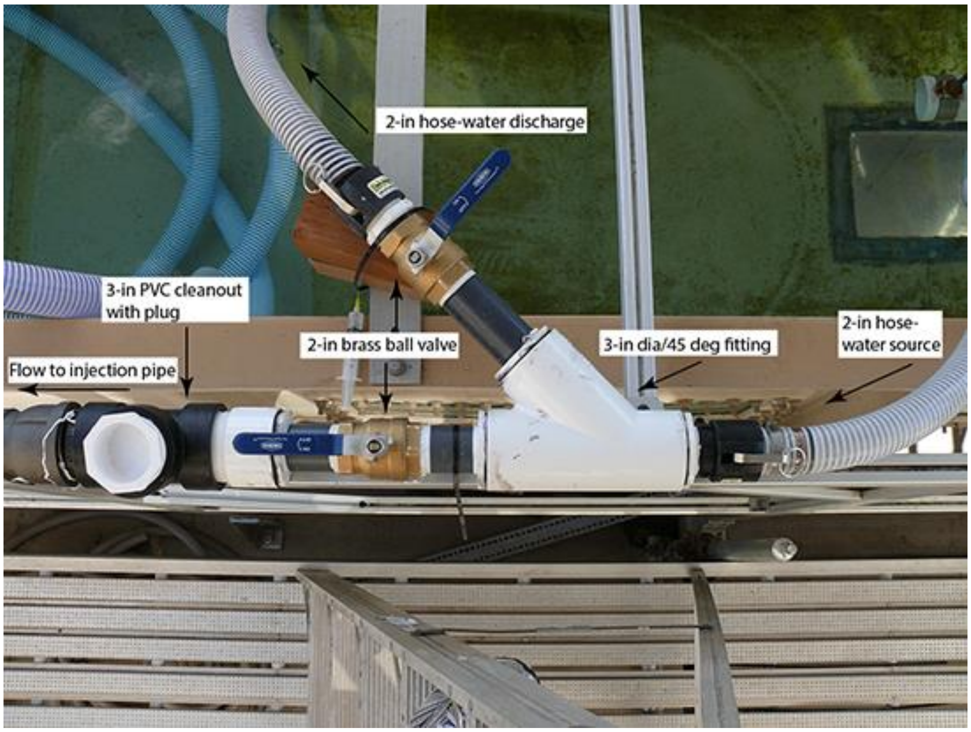


Figure 3.18. Proposed fittings and configuration for a SF injection junction system used to inject SF and water down the flex hose.

Equipment Trailer (Optional)

It is recommended to use an environmentally controlled equipment trailer for equipment storage and office space. Equipment trailer location preference as of 2014 is in front of the Removable Spillway Weir (RSW) control shed roll up door (Figure 3.19); however, an alternate location is located across the intake deck, downstream of the RSW control shed. Both of these locations have enough room to house an 8’ x 12’ trailer and both locations are near 480V and 120V power outlets, both outlets are located at Spillbay 1. Ice Harbor Dam staff may suggest an appropriate location prior to study implementation and project support will be required to connect power to an equipment trailer.

Figure 3.19. Optional trailer location in front of the RSW control shed.

3.2.2 Data Collection

Information related to the SF release and data collection process is described below.

3.2.2.1 Software

Sensor Fish Communicator software, developed by the PNNL Bio-Acoustic and Flow Laboratory, is required for communicating with the SF. The software allows data collection parameters to be preset, data downloaded, and data presentation in a graphic format for immediate review. A SF docking station and available USB port with Virtual COM port (VCP) driver are also required.

The SF Communicator software allows communication with the SF via the docking station. Once the SF Communicator software is installed, interfacing with SF can commence. The communication (COM) port is selected from the dropdown list, which activates the serial port connection. The SF docking station is recognized as four separate COM ports allowing data to be downloaded from four SF simultaneously.

Figure 3.20 shows the options available when readying the SF for data collection. To ready a SF for release, the first step is to click the Version Number button to check that the SF is properly connected to the docking station. The Erase button is then clicked to erase any previously obtained data. Next the delay time, which is the time from when the SF is activated to when data collection starts, is set by typing the number and clicking the Set Delay Time button. Programming of the recording time (i.e., the total time data will be collected) and the resurface time (i.e., the time between when the data collection ends and when the recovery system is activated and the weights that control buoyancy are dropped) are done at the same time.

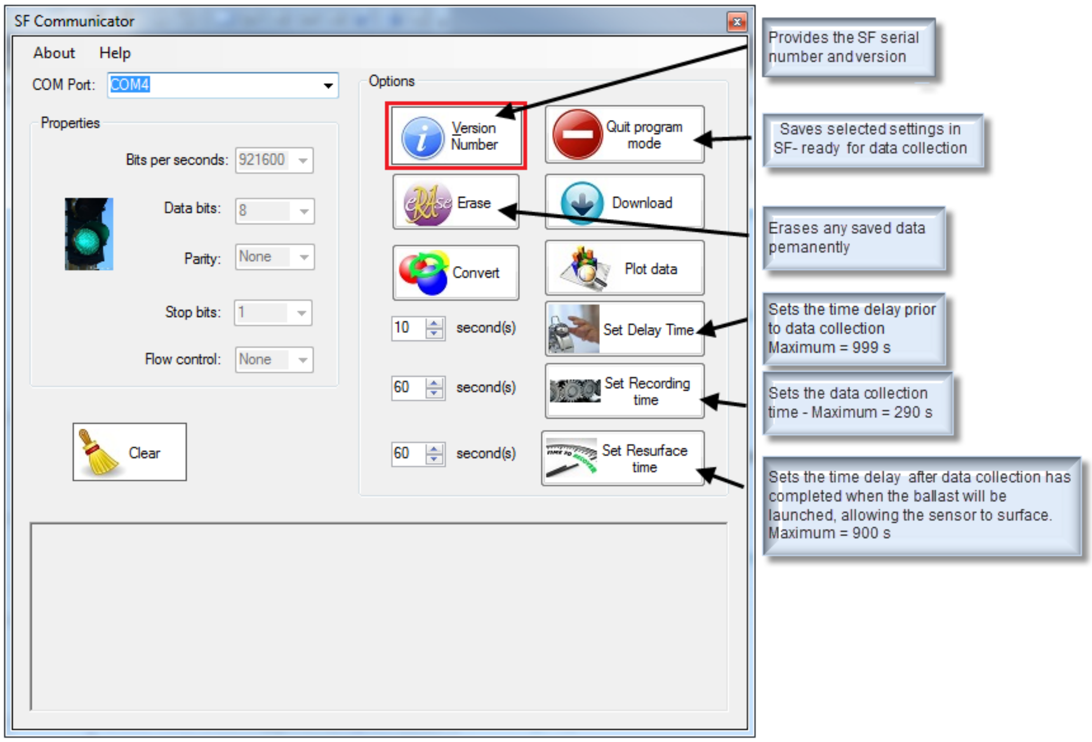


Figure 3.20. The SF Communicator options for data collection.

Once all options are selected, selecting the Quit Program Mode button saves the settings and the SF is ready to be deployed. To activate (trigger) the SF for data collection, a magnet is placed against the side of the housing near a magnetic switch (Hall effect sensor) located on the circuit board. The SF then performs a self-check to make sure that the battery voltage is above a preset threshold and the flash memory is empty. A successful check causes the status LED to flash yellow indicating the start of a configurable data acquisition delay time; otherwise, the status LED flashes red. After the delay time has elapsed, the SF starts collecting sensor data and saving it to flash memory. Once data acquisition is complete, the status LED first flashes green indicating the start of a configurable resurface time. After the resurface time has elapsed the SF activates the recovery mechanism. Finally, the LEDs and RF transmitter are activated periodically until the SF is located and the magnetic switch is tripped.

Following recovery, the data is downloaded from the SF. The unit is placed into the SF docking station and the SF Communicator software is launched. Selecting the Download button activates retrieval. A window will open allowing the user to specify a file name and location. File names for SF should always include the serial number as the first four digits, followed by an underscore and the desired designation. The default file name format is 0001_YYYYmmddhhMMss (SF serial number, year, month, day, hour, minutes, and seconds of the data download time). If the user enters a different file name, the SF serial number and download time are appended to the end of the filename for subsequent quality control. Raw sensor reading data is saved in a .raw2 format and the converted data (using calibration coefficients) is saved in the .csv format. File conversion advancement will be indicated in the progress pane (Figure 3.21). To see a graphic representation of the measurements to check the data quality, the Plot Data button is clicked.

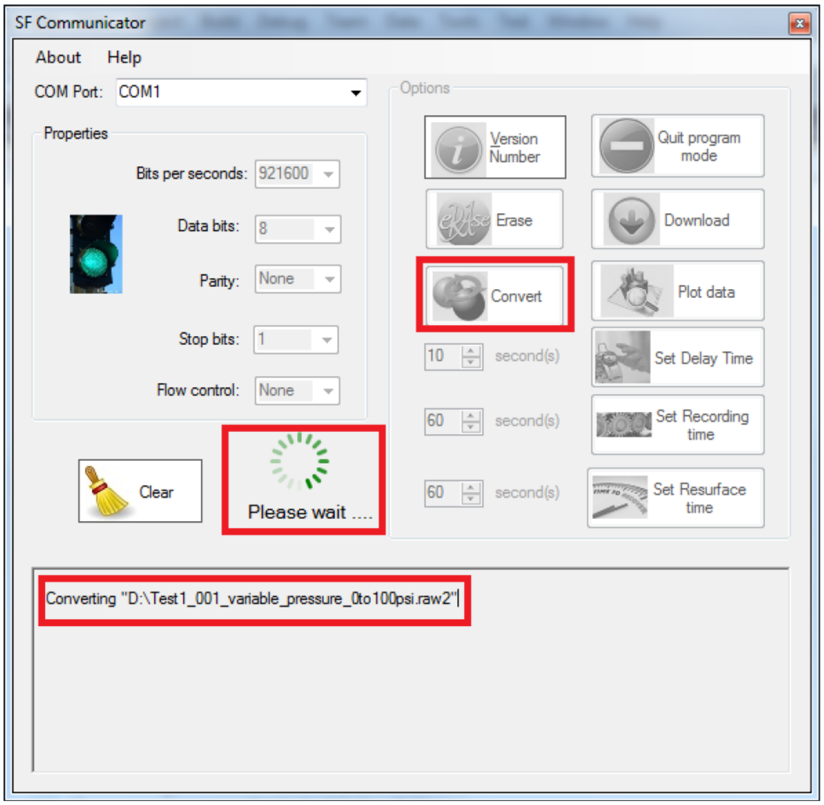


Figure 3.21. The SF file conversion.

3.2.2.2 Sensor Fish Release

The SF will be readied for release and metadata for each treatment will be recorded – either written or electronically logged. Release preparation includes erasing the SF memory, configuring the deployment timing options, and preparing the recovery system of the SF. Preparing the recovery system includes attaching recovery modules, with the Tungsten weights already tied on, to each end of the SF, attaching balloon tags to the SF end caps if desired, and attaching an external radio tag. Once the release preparations are completed and the SF is ready to be released the radio tag is activated (activation method depends on tag type used) and SF is trigger by holding a magnet over the side of the SF. The SF will then blink once a second for the duration of the programmed delay time before it begins to record data. After data collection begins the SF is allowed to record several seconds of data to collect pressure measurements corresponding to the atmospheric pressure before it is put into the release system.

In groups of ten, SF will be released into the injection tank with approximately one minute between individual SF releases. After all ten SF of the group have been released, the contractor staff in the boats will be allowed to recover all of the SF before the next group of ten are released. While the next group is being released one boat will transport the previous group of SF to the shore to be transported back to the powerhouse deck. Radio communication will be maintained between the boaters, the IHR Control Room, and onshore staff for metadata collection and as a safety measure.

SF will be released directly into the turbine intake at predetermined elevations (Figure 2.4) through the CENWW-approved deployment system. Release time and unique SF ID will be recorded as each unit is released from the injection system.

3.2.2.3 Sensor Fish Recovery

A minimum of two boats will be required for SF retrieval – a minimum of one boat for tracking and one as the designated safety boat. The safety boat will be on alert and will stand by to be available should problems with the tracking boats occur. Two staff members will be in each boat, along with all required safety gear and personal protective equipment.

Recovery boat personnel will use radio telemetry receivers to determine the location of the SF relative to boat position and will visually track each SF until accessible for retrieval by netting. SF that fail to surface shall be tracked for a minimum of 30 minutes; if not recovered, periodic checks shall be made to determine whether the tag is stationary (possibly detached) or still actively moving. Once the SF are in the boat, the tracking crew will report the recovered SF ID via radio to the release team and it will be placed into a bucket or other container until approximately ten units have been recovered. One boat will collect the SF from the other boat and transport the units to a staff member located at a safe transfer location onshore (south shoreline). This location will be prearranged and approved by CENWW personnel. The SF will be transported to the intake deck equipment trailer for download to a computer. Data download is accomplished using SF Communicator software (Section 3.2.2.1). After download, acquired data will be plotted and a preliminary review of the data will ensure that no damage to the transducers occurred during passage. If the data is judged as acceptable, SF will be reset and readied for redeployment. Data will be periodically backed up to a data storage device. SF will be deployed following these specified procedures, until sample totals have been completed for each treatment.

3.2.3 Data Management and Analysis

The varied and numerous sources of data that must be combined for successful analysis of a large SF study requires careful data collection and management, efficient data processing, and powerful analysis tools. This section describes how those functions are achieved for this study.

3.2.3.1 Data Management

After a release group of SF has been recovered and transported back to the powerhouse deck, the raw data will be downloaded from the SF and converted to physical units based on the calibration coefficients of the individual SF. The data will be stored on the local hard drive of the laptop as well as on a USB thumb drive for redundancy. Upon returning to the office the entire data set will be backed up onto an external hard drive and the data, along with the field notes and operational details will be uploaded to the SF database for further analysis.

3.2.3.2 Data Analysis

Once the data has been uploaded to the database, each data file will be opened in a utility of the database used for visually inspecting the data and placing timing marks corresponding to when the SF has:

T0: exited the release pipe
T1: entered the wicket gate region
T2: entered the runner region
T3: entered the draft tube region
T4: entered the tailrace region.

After creating the timing marks, plots are created showing the pressure, acceleration magnitude, and rotational velocity magnitude overlaid with the timing marks. The data is then sent to a MATLAB based script that identifies quantities such as the number, type (shear or strike), and severity of acceleration events in each turbine region; the flow quality in each turbine region; and the nadir pressure after passing the runner. After all of the data files have been processed, a summary file will be output from the database to be used for the statistical analysis.

3.2.3.3 Statistical Analysis

SF data collected at the various turbine units will be analyzed to characterize the mean, VAR and distribution of nadir pressures, collision frequencies, shear and turbulence of the SF passage through the turbines. Analyses will include tests of turbine comparison, summary tables, and figures as needed to characterize the study results.

Statistical analysis of acquired SF data will be performed under a subcontract to the University of Washington.

3.2.4 Quality Assurance/Quality Control

Prior to the field evaluation the SF will be calibrated and tested (See Section 3.2.1.2) to validate the standardization of the data collected. Once downloaded, data will undergo a series of data processing steps to assure its quality prior to assembling it into a database with associated metadata, identifying the time, treatment, and conditions under which it was acquired.

3.2.4.1 Standard Procedures and Elements

Numerous standard procedures and elements will be involved with QA/QC, many of which were explained previously in the context of implementation. Procedures will address the need to do the following:

- Develop, peer-review, and finalize the Experimental Design.
- Perform detailed acceptance testing for manufactured/procured equipment.
- Train personnel.
- Visit and inspect the entire data collection and analysis process.

- Perform thorough system checks of telemetry equipment.
- Treat all releases the same as much as possible logistically.
- Archive fundamental data, including metadata, to support alternative or future analysis.
- Institute formal contractor version control and documentation for analysis software.

3.2.4.2 Data Diagnostics

Data diagnostics, along with assumption testing (described in the next section), will ensure that the data are ready for release to the CENWW. The diagnostic process will be structured and systematic. The results will not be reported to the USACE; rather they will be used strictly for internal QA/QC. Data diagnostics include the following topics: atmospheric pressure check, release elevation estimate, and turbine region timing, and are discussed below.

Atmospheric Pressure Check

Prior to placing each activated SF into the release system, several seconds of data will be collected with the SF in the air. The pressure recorded by the SF during this time will be compared with the manually recorded barometric pressure for that release. Any anomalies detected will be investigated thoroughly.

Release Elevation Estimate

After each SF data file has been analyzed to obtain the timing marks, the release elevation is estimated. At the timing mark corresponding to the SF exiting the release pipe (T0), the pressure is converted to a depth using the recorded atmospheric pressure. This depth is then converted to an elevation using the forebay elevation recorded in the dam operations. The estimated release elevation is used to confirm that the data files belong to the correct release groups.

Turbine Region Timing

For each release group, the time that each individual SF release spent in the different turbine regions will be compared. If major discrepancies are identified the corresponding data file will be investigated to attempt to understand the cause.

3.2.5 Reporting

Reporting will consist of a preliminary data summary report, a draft final report, and a final report for each year of testing. An oral presentation of study results will occur annually at the Anadromous Fish Evaluation Program (AFEP) Research Review Meeting. Following the completion of all turbine evaluations, a comprehensive turbine passage comparison document will be produced, following the same guidelines as the individual turbine assessment reports.

3.2.5.1 Preliminary Data Summary Report

A summary of SF releases, metadata associated with the releases (date, time, treatment parameters, and operational conditions), and data quality results (transducer success/failure, losses) will be provided to the CENWW POC no later than 60 days following completion of the field evaluation.

3.2.5.2 Draft Final Report

A draft final report will be submitted to the CENWW POC no later than 6 months after the completion of data collection. A 30-day review period by the AFEP Studies Review Work Group (SRWG) will occur after the submission of the draft final. Comments will be provided to the principle investigators for resolution and incorporation into the final report.

3.2.5.3 Final Report

A final report will be submitted to the CENWW POC containing a thorough description of the methods, analyses, results and implications for management. Methodologies and techniques, including statistical analyses, and pertinent field (operational) observations will be included, as well as resolutions to draft review comments. The final report will be suitable for reproduction and will be submitted no later than 60 days following submission of comments from the AFEP SRWG.

3.3 Bio-Testing

3.3.1 Preparation

The main categories of preparation are equipment, procurements, personnel and logistics, training, and deployment. Preparation will be complete when all equipment hardware and software have been finalized, all procurements have been received and accepted, all personnel have been designated and logistics completed, all equipment have been tested and certified as being ready to collect data. Plans for the BTT injection system will be designed, approved, and constructed and all needed equipment will be acquired.

3.3.1.1 Equipment

Balloon-tagged fish will be used to determine the biological effects of passage through the turbine environment. SF will be deployed in conjunction with balloon-tagged fish to correlate the injuries observed with the turbine environment fish are exposed to. Equipment will consist of BTT, BTT injection system, BTT recovery and injury assessment materials, SF, and associated SF equipment as described in Section 3.2.1.1. To describe the system in brief, balloon-tagged fish are prepared and balloon tags are activated on the intake deck. They are then released down into the turbine intake through the injection system. Finally, each balloon-tagged fish is recovered in the tailrace river environment with two or more boats and survival rates, as well as any injuries acquired during passage, are recorded. Control releases will also occur by releasing balloon-tagged fish directly into the tailrace environment via control release pipes.

Balloon Tags and Radio Telemetry Transmitters

BTT is commonly used to investigate the biological effects of turbine passage on fish. This technology allows researchers to readily recapture fish after turbine passage to examine survival rates, as well as any injuries that occur during the passage. BTT requires two balloon-tags and one radio transmitters to be attached to each fish released. Radio receivers and antennas will be needed to recover fish from the tailrace after release through the turbine or control release pipes. (NOTE: At this time, these studies only include surface acclimated fish, and so results may not accurately demonstrate the effects of rapid changes in pressure; however, they are useful for examining injuries due to strike, shear forces, and predation attempts in the tailrace environment).

Balloon-Tag Technology Injection System

The BTT injection system will be similar to the system described for SF release. See Section 3.2.1.1. for detailed information.

Balloon-Tag Technology Recovery and Injury Assessment Materials

A minimum of two (2) boats are required to support BTT recovery efforts in the IHR tailrace. The contractor shall coordinate with IHR staff to determine equipment, boat, and motor size requirements, and BRZ access (Appendix H) and permitting requirements for operating in the tailrace. Additional equipment recommended to support BTT recovery is listed in Appendix B, Table B.3.

Inventory

Inventory for all BTT equipment with a value greater than $300 and not considered expendable will be monitored by CENWW using barcode readers and a common database. The contractor's inventory database will correspond to the CENWW's database. Each piece of equipment will be assigned a deployment location that will be updated throughout the season as maintenance issues arise and hydrophones and/or equipment are replaced or repaired. The inventory will be provided to the CENWW POC annually in December.

3.3.1.2 Procurements

Procurement needs will be communicated to Brad Trumbo (CENWW POC). Unless noted otherwise, contractor-procured shipments will be delivered to the contractor. The responsible receiving party will enter the procurement into a formal receipt log. Procurements will not be documented as complete until the product or tool has been tested and confirmed to be ready for use in the study. Close coordination with CENWW staff will be required as the testing schedule and IHR project support schedule will effect timing of when equipment should be ready (e.g., installation of injection pipes on the STS). All equipment will need to be procured far in advance to meet these schedules. A comprehensive list of equipment that must be procured can be found in Appendix B, Table B.3.

Radio Telemetry Equipment

A variety of radio telemetry equipment will be procured for this study. Radio receivers, transmitters, and antennas all shall be purchased in the frequency range of 164 to 168 MHz. Resources can be saved by coordinating purchases between the BTT and SF studies. Radio telemetry equipment in the 164 to 168 MHz range has been purchased from ATS; however, the vendor will be re-evaluated by CENWW and the contractor prior to future purchases.

Balloon Tags and Injection System

Balloon tags and injection pipes will be procured directly by the contractor. All engineering drawings must be approved by CENWW prior to purchase. All other components of the injection system are off-the-shelf elements and will be procured by the contractor.

3.3.1.3 Personnel and Logistics

This section details the labor plan for all SF data collection and analysis outlined in this IP. The staff required to complete all tasks will be coordinated by the contractor. The contractor may also work with subcontractors to fill some roles.

Labor Plan for Data Collection and Analysis

The number of personnel required estimated for the completion of each task is listed in Table 3.9. The number of individuals required to complete the tasks outlined in the schedule may vary depending on the abilities and commitments of personnel involved.

Table 3.9. Number of individuals at each position level needed to complete each task. This number may vary contingent on personnel's abilities and commitments. All personnel are required to participate in at least one activity within a given task.

Task	Timeline	Specific Activities	Position	Number of individuals required
1-Attend Pre-Work Meetings/Management	12/1/XX-9/30/XX	a) Coordinate activities with CENWW district staff b) Coordinate activities with IHR project staff c) Finalize experimental design	Chief Scientist	1
			Senior Biometrician	1
			Senior Biological Scientist	1
			Biological Scientist	1

Table 3.9. (contd)

Task	Timeline	Specific Activities	Position	Number of individuals required
2-Preseason/Planning	12/1/XX-2/28/XX	a) Procure equipment and supplies b) Acceptance testing of equipment c) Training of personnel d) Staff/Equipment planning e) Set-up subcontracts f) Deployment coordination g) Site visits	Chief Scientist	1
			Senior Biometrician	1
			Senior Biological Scientist	1
			Biological Scientist	2
			Biological Science Technician	4
3-Deployment/Demobilization	2/1/XX-2-28/XX	a) Deployment coordination b) Deploy/test fish injection system c) Demobilize fish injection system	Biological Scientist	2
			Biological Science Technician	2
4- Fish Releases	3/1/XX-3/31/XX	a) Daily operations coordination b) Staff/Equipment planning c) Release/recover Balloon-tagged and Sensor Fish	Senior Biological Scientist	1
			Biological Scientist	3
			Biological Science Technician	4
5-Data Collection/Processing	3/1/XX-9/30/XX	a) Archive data b) Process data c) Data diagnostics d) Statistical analysis	Chief Scientist	1
			Senior Biometrician	1
			Biological Scientist	2
			Biological Science Technician	2
6-Prepare Deliverables	3/1/XX-9/30/XX	a) Prepare preliminary reports b) Prepare annual report	Chief Scientist	1
			Senior Biometrician	1
			Biological Scientist	2
			Biological Science Technician	2

3.3.1.4 Training

Staff assigned to deploy and recover the balloon-tagged fish and SF in the field environment will be experienced and knowledgeable of this process, as well as in boat operations, operation of radio telemetry equipment, identification of typical injuries observed on turbine-passed fish. This training will be provided prior to data collection by experienced staff members and may occur through reading assignments, discussion, watching videos, observation by trainees of tasks being performed, immediate supervision of trainee performing task and if/when deemed appropriate by trainer, the trainee may perform the task independently.

Balloon-Tagged Fish and Sensor Fish Injections

Training activities related to the preparation and injections of SF include:

- Fish anesthesia and euthanasia
- Attaching balloon tags to fish
- Activating balloon tags
- Deploying the fish using the release system
- Tying the Tungsten weights onto the recovery circuit boards
- Attaching balloon tags to the SF end caps
- Using the SF software, SFCommunicator, to configure the SF for a release
- Deploying the SF using the injection system
- Using the SF software, SFCommunicator, to download and convert the data

All staff who will work on the powerhouse intake deck releasing balloon-tagged fish and SF will complete this training. Training for all activities will take place in at the contractor's facility and will be supervised by experienced staff members.

Balloon-Tagged Fish Recovery

Training activities related to the preparation and operation of radio telemetry equipment:

- Use of radio telemetry receivers
- Methods for identifying the locations of radio-tagged balloon-tagged fish and SF
- Identification and categorization of injuries commonly observed on turbine-passed fish
- Fish anesthesia and euthanasia
- Boat operations in the tailwater environment that meet the contractor's and CENWW requirements

All staff who will work on the powerhouse intake deck releasing balloon-tagged fish and in each recovery boat will complete this training. Training for all activities will take place outdoors.

3.3.1.5 Deployment

Holding tanks will be set up prior to fish delivery and will be supplied with constant ambient river water via pumps. Two pre-testing tanks shall be positioned near the release locations, to provide easy access to test fish for tagging. A minimum of three post-testing holding tanks will be necessary to monitor the survival and behavior of test fish for up to 48 hours following release. These tanks will be deployed at a location selected by IHR staff.

Deployment of the turbine intake system injection system will occur as described in Section 3.2.1.5. The lateral location(s) and position(s) of fish injection pipes will be determined by CENWW staff prior to the initiation of the study and communicated to the study contractor. Release locations will be determined and verified through physical hydraulic model investigations at the Engineer Research and Development Center (ERDC) 1:25 scale model of Ice Harbor turbine, located in Vicksburg, Mississippi, prior to beginning of the field evaluation. Additional injection system equipment, for example injection pipes for control fish releases, locations will be dictated primarily by the study location on the dam. A crane, operator, and riggers to install and remove the release pipes and receiving copies of electronic project operation data for the test turbine unit in 5-minute increments will need to be directly coordinated with CENWW, if necessary.

3.3.2 Data Collection

3.3.2.1 Fish Collection, Tagging, and Release

All personnel performing fish collection, tagging, release, and recovery work will be properly trained and must adhere strictly to USACE and IACUC guidelines for collecting, transporting, handling, and holding fish.

Federal and State Permitting

Applications for both federal (NMFS) scientific collection permits and state (WDFW) transport permits will be submitted in the winter prior to the study year. The ability to tag smolts is contingent on obtaining approval from NMFS and WDFW to collect, mark and transport the number of fish suggested in the experimental design. After permits have been obtained, records will be kept on all smolts handled and used for testing.

Fish Collection

Spring Chinook salmon will be acquired from a local hatchery prior to the beginning of the study. Contractor staff will transport hatchery fish to IHR inside insulated totes supplied with oxygenated river water. Oxygen tanks (2,200 psi) will be secured to the bed of the transport truck and will maintain dissolved oxygen levels in the totes between 80% and 110%. Temperature will be maintained in the totes with the addition of ice made from river water, if necessary. During transport, temperature and dissolved oxygen will be monitored via an instrument cable running from the tote to inside the transport vehicle. Once at IHR, untagged fish will be held in holding tanks with flow through river water prior to surgery.

Fish Tagging

Five to ten fish per lot will be randomly moved from holding tanks to the adjacent tagging site using a water sanctuary equipped net. Fish displaying abnormal behavior, severe injury, fungal infection, or descaling (>20% per side) shall not be used. The same fish selection criteria shall be applied to all treatment and control groups. Fish shall be anesthetized in a 20-80 mg/L clove oil solution (or 80 mg/L MS-222 solution buffered with 80 mg/L sodium bicarbonate) to Stage 4 anesthesia.

Fish will be equipped with a radio transmitter, and two balloon tags (Figure 3.22). The balloon tags and radio transmitter shall be attached via SS pins inserted through the musculature beneath the dorsal and adipose fins. A uniquely numbered Visible Implant tag (VI) shall also be inserted in the post-ocular tissue for use in tracking 48 hour survival of individual recaptured fish because the radio transmitter and balloon tags will be removed after recovery. Fish shall also receive a unique fin clip in the event the VI tag becomes dislodged.

Figure 3.22. Juvenile salmonid equipped with a radio transmitter and two balloon tags.

After fish are tagged, five to eight fish will be placed in a 20 gallon (75 L) tub continually supplied with ambient river water until fully recovered from the anesthesia (30 to 45minutes, minimum 20 minutes). Following recovery from anesthesia, fish will be transported in the 20-gallon tubs (75 L) to the release site.

Balloon-Tagged Fish Release

NOTE: The traditional fish release system for balloon-tag studies does not allow for the depth acclimation of fish prior to passage; therefore, passage effects due to pressure may not be obtained using this system.

All treatment and control fish will be released through an injection system continuously supplied with river water. The induction system will consist of a small holding basin attached via PVC piping to a 4-in. diameter flex hose connected to the SS injection piping (Section 3.2.1.1), which will allow exit at the approved elevation for each treatment (Figure 3.14). Fish shall be held individually in water within the induction system holding basin while the balloon tags are activated (by injecting water using a syringe and needle), and then released into the stand pipe.

Radio telemetry transmitter codes will be verified prior to activation and boat crews will be notified via 2-way radio the radio frequency for each release, allowing the crews to preload the codes into the receivers. This will allow multiple frequencies to be scanned during fish recovery.

Balloon-Tagged Fish Recovery and Observation

A minimum of two boats will be required for BTT and SF retrieval – a minimum of one boat for tracking and one as the designated safety boat. The safety boat will be on alert and will stand by to be available should problems with the tracking boats occur. Two staff members will be in each boat, along with all required safety gear and personal protective equipment.

Following passage through the turbine unit or control point, boat crews will use antennas coupled to radio receivers to track the fish via their radio transmitter, until the fish come to the water surface by the inflation of the balloon tags. Tags that fail to surface shall be tracked for a minimum of 30 minutes; if not recovered, periodic checks shall be made to determine whether the tag is stationary (possibly detached) or still actively moving. Boat crew members will retrieve the fish using dip nets, remove the balloon and radio transmitter, and place fish into an on-board 5-gallon (20 L) bucket containing aerated river water. The crew will examine the recaptured fish for injuries and will assign an appropriate condition code that categorizes injuries by type, coverage, and area on the body where it occurs (Table 3.10; Normandeau 2013). Boat crews will notify deck personnel of the fish recovery time and any applicable condition codes. Fish will be transported to an onshore holding tank, continually supplied with river water. Fish will be monitored at approximately 12-h intervals. Dead fish will be identified by the VI tag (or fin clip), examined for external injuries, and necropsied to determine the potential cause of death.

Table 3.10. Sample list of condition codes for fish passage survival studies (Normandeau 2013).

Status Code	Description
*	Turbine/passage-related malady
4	Damaged gill(s): hemorrhaged, torn or inverted
5	Major scale loss, >20%
6	Severed body or nearly severed
7	Decapitated or nearly decapitated
8	Damaged eye: hemorrhaged, bulged, ruptured or missing, blown pupil
9	Damaged operculum: torn, bent, inverted, bruised, abraded
A	No visible marks on fish
B	Flesh tear at tag site(s)
C	Minor scale loss, <20%
E	Laceration(s): tear(s) on body or head (not severed)
F	Torn isthmus
G	Hemorrhaged, bruised head or body
H	Loss of Equilibrium (LOE)
J	Major

Table 3.10. (contd)

Status Code	Description		
K	Failed to enter system		
L	Fish likely preyed on (telemetry, circumstances relative to recapture)		
M	Minor		
P	Predator marks		
Q	Other information		
R	Removed from sample		
T	Trapped in the rocks/recovered from shore		
V	Fins displaced, or hemorrhaged (ripped, torn, or pulled) from origin		
W	Abrasion / Scrape		
Survival Codes			
1	Recovered alive		
2	Recovered dead		
3	Unrecovered – tag & pin only		
4	Unrecovered – no information or brief radio telemetry signal		
5	Unrecovered – trackable radio telemetry signal or other information		
Dissection Codes			
1	Shear	J	Major
2	Mechanical	L	Organ displacement
3	Pressure	M	Minor
4	Undetermined	N	Heart damage, rupture, hemorrhaged
5	Mechanical/Shear	O	Liver damage, rupture, hemorrhaged
6	Mechanical/Pressure	R	Necropsied, no obvious injuries
7	Shear/Pressure	S	Necropsied, internal injuries
B	Swim bladder ruptured or expanded	T	Tagging/Release
D	Kidneys damaged (hemorrhaged)	U	Undetermined
E	Broken bones obvious	W	Head removed; i.e., otolith
F	Hemorrhaged internally		

Sensor Fish Release and Recovery

SF release and recovery procedures will follow those outlined in Sections 3.2.2.2 and 3.2.2.3.

3.3.3 Data Management and Analysis

The varied and numerous sources of data that must be combined for successful analysis of a large BTT study requires careful data collection and management, efficient data processing, and powerful analysis tools. This section describes how those functions are achieved for this study.

Data including, but not limited to, discharge, fish release and recapture times, fish condition, status after holding, etc. will be recorded along with specific transmitter frequencies. Data will be analyzed and 48-hr survival estimates and injury rates will be calculated for all treatments.

Data Management

Data will be collected on data sheets and entered into an Excel spreadsheet at the end of every field day. These data sheets will also be scanned and archived in .pdf format. Upon returning to the office, the entire data set will be entered into a database and archived .pdf files will be backed up onto an external hard drive.

Statistical Analysis

Statistical analysis examining the 48-hr survival rates and the likelihood of injuries will be conducted by the University of Washington under a separate contract.

3.3.4 Quality Assurance/Quality Control

Prior to the field evaluation the SF will be calibrated and tested (See Section 3.2.1.2) to validate the standardization of the data collected. Once downloaded, data will undergo a series of data processing steps to assure its quality prior to assembling it into a database with associated metadata, identifying the time, treatment, and conditions under which it was acquired.

Data recorded on data sheets will be entered into an Excel spreadsheet and data will be checked by at least two contractor staff to ensure quality control of transcribed data. Additionally, there are several standard procedures and elements that will be adhered to as are described below.

3.3.4.1 Standard Procedures and Elements

Numerous standard procedures and elements will be involved with QA/QC, many of which were explained previously in the context of implementation. Procedures will address the need to do the following:

- Develop, peer-review, and finalize the Experimental Design.
- Perform detailed acceptance testing for procured equipment.
- Train personnel.
- Perform thorough system checks of telemetry equipment.
- Visit and inspect the entire data collection and analysis process.
- Document the percentage of fish tagged out of the total number handled; document the percentage of handling mortality.
- Treat all releases the same as much as possible logistically.
- Archive fundamental data, including metadata, to support alternative or future analysis.
- Institute formal contractor version control and documentation for analysis software.

3.3.5 Reporting

Reporting will consist of a preliminary data summary report, a draft final report, and a final report. An oral presentation of study results will be presented at the AFEP Research Review Meeting.

3.3.5.1 Preliminary Data Summary Report

A preliminary data report including estimated survival and injury rates for all treatments evaluated will be submitted to the CENWW POC no later than 60 days after the completion of the field study.

3.3.5.2 Draft Final Report

A draft final report will be submitted to the CENWW POC no later than 6 months after the completion of data collection. A 30-day review period by the AFEP SRWG will occur after the submission of the draft final. Comments will be provided to the principle investigators for resolution and incorporation to the final report.

3.3.5.3 Final Report

A final report will be submitted to the CENWW containing a thorough description of the methods, analyses, results, and implications for management. Methodologies and techniques, including statistical analyses, and pertinent field (operational) observations will be included, as well as resolutions to draft review comments. The final report will be suitable for reproduction and will be submitted no later than 60 days following submission of comments from the AFEP SRWG.

4.0 Project Management

The project to conduct the performance assessment study at IHR will be managed in accordance with a Project Management Plan (PMP) required by the contractor. The PMP will be an internal contractor document that will include the statement of work, which will clearly define the project objectives and deliverables. The technical strategy will be clearly communicated, including all activities and approaches and their respective technical issues and assumptions. The management approach will define the resources necessary to conduct the work, discuss performance measurement criteria, cover how changes in scope will be handled, detail management oversight activities, present records management plans, and conclude with procedures for project close-out. The PMP will also include a detailed set of schedules for project activities and major milestones and related deliverables. Project tracking will include project completion status updates as well as project budget updates. The risk management section will identify project risks and present detailed risk mitigation measures that will be used to reduce risks. The PMP will present the approach to QA for the project.

5.0 References

Cook KV, Brown RS, Deng ZD, Klett RS, Li H, Seaburg AG, and MB Eppard. 2014. A comparison of implantation methods for large PIT tags and injectable acoustic transmitters in juvenile Chinook salmon. Fisheries Research 154: 213-223.

Ingraham JM, Deng ZD, Martinez JJ, Trumbo BA, Mueller RP, and MA Weiland. 2014. Feasibility of tracking fish with acoustic transmitters in the Ice Harbor Dam tailrace. Scientific Reports 4: Article Number 4090.

McMichael GM, Duncan JP, Bellgraph BJ, Deters KA, Titzler PS, Harnish RA, Colotelo AH, Ham KD, Stephenson JR, Skalski JR, Townsend RL, Deng ZD, Martinez JJ, Hughes JS, Khan F, Weiland MA, and AC O'Toole. 2011. Implementation Plan for Using Acoustic Telemetry Methodology to Estimate Survival and Passage Metrics at Ice Harbor Dam. PNNL-4319; Pacific Northwest National Laboratory, Richland, Washington.

McMichael GM, Duncan JP, Bellgraph BJ, Deters KA, Titzler PS, Harnish RA, Colotelo AH, Ham KD, Stephenson JR, Skalski JR, Townsend RL, Deng ZD, Martinez JJ, Hughes JS, Khan F, Weiland MA, and AC O'Toole. 2012. Implementaion Plan for Using Acoustic Telemetry and Passage Metrics for the Multidam Performance Study. PNNL-4332, Pacific Northwest National Laboratory, Richland, Washington.

Normandeau Associates, Inc. 2013. Estimates of Direct Effects of Steelhead Salmon during Downstream Passage through a Turbine and Weir at Foster Dam, Oregon. Drumore, Pennsylvania.

Normandeau Associates, Inc., Skalski JR, and RL Townsend. 2008. Turbine Operational Effects on the Survival/Condition of Yearling Chinook Salmon, *Oncorhynchus tshawytscha*, at Ice Harbor Dam, March 2007. Drumore, Pennsylvania.

Pacific States Marine Fisheries Commission. 2009. 2009 PIT Tag Specification Document. Pacific States Marine Fisheries Commission, Gladstone, Oregon. Available at ftp://ftp.ptagis.org/Documents/PTSD/2009_PIT_Tag_Specification_Document.pdf.

Rakowski CL, Serkowski JA, Richmond MC, and WA Perkins. 2010. Determining Columbia and Snake River Project Tailrace and Forebay Zones of Hydraulic Influence Using MASS2 Modeling. PNNL-20030, Pacific Northwest National Laboratory, Richland, Washington.

Summerfelt RC, and LS Smith. 1990. Anaesthesia, Surgery and related techniques. Pp 213- 272, in Schreck CB and PB Moyle (eds.) Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Titzler PS, McMichael GA, and JA Carter. 2010. Autonomous Acoustic Receiver Deployment and Mooring Techniques for use in Large Rivers and Estuaries. North American Journal of Fisheries Management 30(4):853–859.

U.S. Army Corps of Engineers (USACE). 2011. *Surgical Protocols for Implanting JSATS Transmitters into Juvenile Salmonids for Studies Conducted for the U.S. Army Corps of Engineers*. Version 1.0, USACE, Portland District, Portland, Oregon.

Appendix A

Environmental Health & Safety Plan

Appendix A

Environmental Health & Safety Plan

Field Environment, Safety, and Health Plan

<table>
<tr><td>Date: September 2, 2014</td><td colspan="3">Author: J Smith</td></tr>
<tr><td>Project #: 11111</td><td colspan="3">Project Title: Multi-Year Biological Research at Ice Harbor Dam: Turbine Characterization using Sensor Fish and Acoustic Telemetry Study</td></tr>
<tr><td colspan="4">Describe Activities: In 2010, the US Army Corps of Engineers (Corps) awarded a contract to Voith Hydro to work cooperatively with the Corps technical leads to develop two new turbine runner designs to provide a safer fish passage environment. Field work for this project will help characterize the turbine runner environment and estimate fish passage survival at Ice Harbor Dam (IHR) before and after the turbine runner replacement. The contractor will release a SF so that it passes through a current turbine to collect baseline passage environment data and will estimate condition and survival of juvenile salmonids migrating downstream through IHR powerhouse test units. Major activities will include driving rented vehicles to and from the work location on maintained roads; working on the dam in hazardous areas (near cranes, heavy equipment, electrical transformers, etc.) for the purpose of installing and maintaining SF injection systems; transporting SF release equipment to the dam, installing and maintaining Juvenile Salmon Acoustic Telemetry System (JSATS) receiving systems or servicing autonomous nodes with boats; anesthetizing and surgically implanting JSATS acoustic transmitters into the body cavity of juvenile salmonids; transporting tagged fish from the dam to release sites via trucks; towing trailers, boats, and launching boats; on-water boating operations; operating power hand tools; and conducting outdoor work in potentially inclement weather.</td></tr>
<tr><td colspan="4">Work Locations: Ice Harbor Dam</td></tr>
<tr><td>ES&H Hazards:
☒ Chemical
☒Biological
☐ Radiological
☐ NIR: Lasers/RF/ magnetic field
☒ Waste generation/ treatment/disposal</td><td>☒ Electrical hazards
☒ Powered equipment
☒ Manual lifting
☐ Working alone
☒ Work at heights
☒ Industrial site
☐ Use of Firearms</td><td>☒Traffic
☐ Off-road vehicles
☒Boats/water hazards
☐ U/W diving
☐ Aviation
☒Environmental/ temp. extremes</td><td>☒Fatigue/physical stress
☒ Hazardous flora/fauna
☒Hazardous activities nearby
☐ Other dangerous environment</td></tr>
<tr><td colspan="4">☒ Other ES&H risks: Slips, trips, and falls; noise</td></tr>
<tr><td colspan="4">Risk Analysis: The Walla Walla Ice Harbor Dam Characterization Study is considered a medium risk project. This is based on field activities involving boating operations, US Army Corps of Engineers (USACE) dams, driving in inclement weather and on unimproved roads, material handling, and long work hours. Staff supporting these activities will have completed appropriate training to conduct these activities in a safe manner. Task leads have been involved with similar activities and understand the hazards involved with this type of work. Management has evaluated the hazards involving this work and has implemented controls to mitigate injuries/illnesses. The USACE places a high priority on safety and this has been flowed down to the contractor. The contractor will manage and flow down all ES&H requirements to sub-tier contractors as appropriate per contract clauses.</td></tr>
</table>

Hazard Mitigation: Regardless of whether the risk is specifically identified in the table below, all staff, regardless of their role in the project, have the right and the responsibility to stop work immediately when convinced a situation exists that places themselves, their coworkers, or the environment in danger. The Project Manager (PM) has the ultimate responsibility to ensure the safe conduct of work. If new activities are anticipated that are not described in this safety plan, the new activities must first be evaluated and approved by the PM; modifications may require consultation with management and/or safety representative prior to making changes to procedures or protocols.

Prior to initiating any onsite work, USACE and contractor staff will jointly participate in a safety and orientation briefing at IHR that will familiarize all workers with the hazards with working at this dam. All personnel working on USACE dams including IHR must follow the USACE Safety Manual (EM-385 available from the PM). Daily safety meetings shall be conducted for all personnel to discuss work planned, anticipated hazards, and control measures. Identification badges shall be worn and visible at all times, and minimum PPE required at all times while working at IHR includes hard hats, long pants, and steel-toed footwear.

Pagers and cell phones are not required for crews at IHR but all personnel are required to know how to access operators in the Control Room using dam phones on all decks or by cell phone. Dam phones to the Control Room are the preferred method for initiating emergency response. The number to dial the Control Room is clearly posted on every phone – dial extension 231. You can use a cell/satellite phone to call the IHR Control Room at (509) 543-3231.

Activity	Hazard(s)	Hazard Control/Mitigation
Driving – to and from the dams; driving while on the dam deck; and traveling to launch sites in truck/trailer combinations	Collision with another vehicle or object (including animals) while driving between the dam and Richland; vehicle leaving road due to driver fatigue or inattentiveness.	Inspect vehicle prior to use and ensure safety equipment available and in good working order including fire extinguisher, seat belts, and first aid kit. Consider weather, roadway, and other users of the road before departing. Ensure accident reporting information is in glove box including Ecology Group roster with phone numbers. Conduct a 360-inspection before moving vehicle. Practice defensive driving at all times, especially in low or poor visibility. Animals are common on the highway between Richland and IHR at dusk so pay attention. Do not talk on cell phone or text when driving – this is illegal. Do not drive if fatigued – use a buddy.
	Collision with another vehicle, equipment, property, or people while driving on the dam deck due to congestion in work areas, limited turning space, other traffic and work equipment; vehicle moving from parked position and striking person or object.	Conduct a 360-inspection before moving vehicle. Use a spotter to move a vehicle in an area of congestion or tight turning conditions, or when maneuvering a trailer. Practice defensive driving at all times, especially in low or poor visibility. When on dam deck, follow posted speed limits and obey USACE staff regarding when to pass operating equipment (e.g. cranes). Vehicles shall not be left unattended until the motor has been shut off, the key removed, parking brake set, and gear engaged in park. If stopped on a hill or grade, front wheels shall be turned or hooked into the curb or the wheels securely chocked. If necessary mark with orange safety cones, and do not block traffic on the dam deck with a parked vehicle.
	Operating a commercial motor vehicle (CMV)	All contractor and subcontracted staff will be required to have a CMV qualified operator card and complete training course 2283 for towing any trailer in which the gross weight of trailer and truck is > 10,000 lbs (essentially all truck and boat trailer combinations). Staff will record all driving time and time spent operating a CMV on data forms in each vehicle. A complete description of the CMV program including driver inspection and log forms are available from the PM or onsite supervisor.
Working on the dam	Equipment (including cranes) and vehicles moving on deck of dam can strike and injure personnel; falling objects from above or heavy objects dropped on toes.	Personnel shall watch for warning signal lights, signs, and personnel hand signals. Be alert to dangerous situations, and know emergency procedures. Personnel shall wear the appropriate PPE as required (hard hat, long pants, gloves, steel-toed boots, etc.).
	Noise is common near transformers or machinery.	Wear ear plugs (available onsite) to protect hearing.
	Slips, trips and falls in areas that are wet, uneven, sloping, or elevated.	Caution must be exercised to prevent slips on rain slickened surfaces, slopes or loose gravel. Never work on elevated docks or platforms in areas of no guard rails without fall protection and training in its proper use. Wear appropriate footwear for working in wet areas (rubber boots with high-traction sole).

Activity	Hazard(s)	Hazard Control/Mitigation
	Cuts, bruises, and abrasions and back strain from handling heavy, rough, or abrasive objects.	Gloves and steel-toed boots shall be provided and worn when working at a USACE dam, otherwise steel-toed boots are optional and recommended if staff will be frequently working with heavy items. Use proper lifting techniques to avoid back strain. Consider a buddy or mechanical lifting device for awkward/heavy loads. For example, if the object >44 lbs, consider >1 person for lift or use lifting device. However, even if object is light, consider >1 person for lift or lifting device if the lift is awkward; repetitive; or if staff has previous lifting injury/illness that could be aggravated (contact Worker S&H representative if questions). When lifting: • Keep objects close to your body • Do not twist while lifting • Lift with legs and not your back • Use caution when lifting over your head • Minimize repetitive lifts
	Working with and around cranes can result in falling loads, pinch points between loads and rigging, and tripping hazards.	A certified crane contractor and operator will be contracted to do all hoisting of heavy materials. Qualified and experienced staff shall be used to work around cranes. Personnel will be familiar with hand signals. Personnel may have to guide suspended loads into position. Do not stand or walk under a load. Be aware of hand and foot pinching hazards. Wear required PPE (gloves, hard hat, steel-toed shoes, and long pants).
	Falling from the dam into the water or from height could result in injury or death	Fall protection and personal flotation devices (PFD) are required when working outside railings.
	Working at night on the dam increases risk of injury due to poor visibility	Workers should familiarize themselves with their work areas, watch their footing, and use additional lighting as necessary. Work only within handrails and safety rails at night. Know locations of emergency telephones, fire extinguishers, first aid kits, and flashlights (available in every work trailer, truck, and boat). Use the buddy system.
Fish surgery/handling including anesthetizing fish and sterilizing instruments	Lacerations from scalpels or punctures from suture needles.	PPE and safe work practices – put sharp tools away when not using them. Move slowly around working surgeons. Use sharps container for disposal of scalpels and suture needles. Have first aid kit available with wound care disinfectants and antibiotic ointments.
	Potential for secondary infections from exposure to disease causing organisms.	Disease transmission from fish to workers is very unlikely but maintaining tetanus vaccination can reduce risk if worker has an open wound and is working near water. All workers handling fish should have a cold-blooded animal handler medical exam to verify tetanus is up to date. Have first aid kit available with wound care disinfectants and antibiotic ointments.

Activity	Hazard(s)	Hazard Control/Mitigation
	Chemical exposure to MS-222 or ethanol through contact with skin or through inhalation.	Use vinyl, latex, or nitrile gloves and safety glasses when working with diluted solutions (see Material Safety Data Sheets (MSDS) for MS-222 (tricaine methanesulfonate) and 70% Ethanol; available upon request from field team leader or PM). MS-222 powder is measured on a scale located within a laboratory hood and transferred to a Nalgene variable-volume dispensing bottle. Equal amounts of sodium bicarbonate will be used. While under the hood, distilled water is added to the bottle and the lid is tightened. The container is shaken until the powder dissolves. MS-222 should be stored in a dark, cool location. 70% ethanol is made from 95% ethanol and distilled water also under a laboratory hood. Ethanol should be stored in a flammable-storage cabinet. If skin contact with MS-222 powder or solution occurs, wash with soap and water. Refer to the following MSDS for additional information on hazards and first aid. Keep area where MS-222 and ethanol are being used well-ventilated to reduce overexposure. MSDS sheets for chemicals used are in labeled 3-ring binder located in tagging trailer.
	Waste generation/ treatment/ disposal	MS-222 (tricaine methanesulfate) will be treated and discharged following conditions for discharge according to Washington state and USACE protocols. Ethanol (ethyl alcohol 95%/70%), used as a disinfection agent, will be transported, stored and managed as hazardous material. See MSDS for specific hazard information and warnings including manufacturer guidance.

Activity	Hazard(s)	Hazard Control/Mitigation
Boating – transporting SF to shore recovery site.	Operating boat in the river, especially in adverse weather or water conditions, could result in capsizing or swamping, or cause occupants to be thrown from the boat, all which have the potential for drowning or injuring occupants.	Selection of the proper boat is critical to mitigating hazards. All boats will have sufficient room, freeboard, and stability to safely carry cargo and crew with consideration given to the weather and water conditions in which they will be operated. PM is ultimately responsible to ensure the proper boat(s) is used for the task. Boats will be operated by a qualified operator who has experience with the boat and is familiar with the work locations. Motorboats shall meet minimum flotation requirement of the US Coast Guard (USCG) and carry all the required safety equipment. Every crew member will wear a Type III PFD and the boat will have at least one Type IV PFD aboard. PFDs will be inspected prior to and after each use for defects that would alter their strength or buoyancy. Defective PFDs will be removed from service and replaced. Wear appropriate clothing for field work in a wet environment. If personnel end up in water, perform man-overboard rescue. Remove wet clothing immediately and seek shelter from environmental conditions. Administer first aid as necessary. Boats used at night will be equipped with GPS sonar navigation and spot lights. Stay alert to weather bulletins. Boat work may be cancelled if wind conditions create hazardous wave conditions. All personnel also have the authority to cancel boat work if they do not feel comfortable with prevailing conditions. Watch for obstructions in the water. Do not operate boats beyond factory requirements for speed and maneuvering. A float plan (available from the PM, or delegate) will be filed with the contractor Operations Center daily. Use radio or other communication device (e.g. cell phone, satellite phone, etc.) to communicate with dam or onshore personnel. Ensure that the communication device will be operational in the event of unexpected water exposure, i.e., use dry bag or other means to ensure it stays dry.

Activity	Hazard(s)	Hazard Control/Mitigation
	Operation of a boat within the BRZ could result in a loss of power which could result in contact or impingement with the dam.	Follow all rules and regulations outlined in BRZ entry plan (available from the PM or onsite field manager). If clearances are required all staff will be trained according to Corps of Engineers Walla Walla District (CENWW) guidelines and submit the required forms including the Activity Hazards Analysis form. Contractor staff will be responsible for holding clearances for lockout devices prior to conducting any operations within the BRZ. Prior to holding a clearance to lock out any device at IHR, contractor staff are required to learn the CENWW clearance policy and take an examination.
	Potential exposure to carbon monoxide during boat operations.	Minimize idling time while docked or limit staff time in the stern while idling. Carbon monoxide (CO) cannot be seen or smelled, but it can kill you or make you sick. Know the symptoms of CO poisoning: • headache • confusion • fatigue • seizures • dizziness; loss of consciousness • nausea. Get to fresh air and seek medical help immediately if you or a coworker has these symptoms! CO from engine exhaust builds up inside and outside the boat in areas near exhaust vents. Stay away from these areas while propulsion engines, generator, or other internal combustion equipment are running. Schedule regular engine and exhaust system maintenance inspections by experienced and trained technicians. Be aware that dangerous concentrations of CO can accumulate within seconds.
	Transporting invasive weeds mussels or tunicates from one body of water to another	For all watercraft recoveries, complete a self-inspection of all parts of the boat, both inside and outside of the hull, and trailer. Remove all aquatic weeds and fragments prior to leaving the boat recovery area. See PM or delegate for protocols that staff will follow when retrieving boats from the Snake River.
Operating power tools	Entanglement of clothing, hair, rings, etc.; high-velocity particles from grinding and cutting; cuts and abrasions; elevated noise levels.	Keep loose clothing, hair, etc., clear of work. Face and/or eye protection shall be worn when loose or flying materials are present. Use hearing protection for excessive noise levels. Gloves shall be worn while operating stationary power tools (e.g., drill press, grinder, lathe, etc.). Always cut away from body.

Activity	Hazard(s)	Hazard Control/Mitigation
	Electric shock	Do not use any electrical item that is defective or shows evidence of damage that could expose a worker to injury until repaired, replaced, and tested. Use contractor or CENWW guidelines to determine if lock and tag out procedures should be used prior to any electrical work. Use grounded (3-prong plug) tools and extension cords rated for hard or extra hard usage. Portable cord and plug equipment and extension cords shall be inspected daily before use for any defects of the following: • Loose parts • Deformed/damaged or missing pins • Damage to outer jacket or insulation • Evidence of internal damage such as pinched or crushed outer jacket Damaged corded equipment and extension cords will be removed from service until repaired or replaced. Electrical cords will be protected from damage caused by foot traffic, vehicles, sharp corners, projections and pinching. GFCIs will be used and function tested daily before use.
Conducting work outdoors	Sun burn/UVB exposure, erythema of skin or blistering. Long term effects of increase risk of melanoma.	Be cognizant of medications, chemicals, or cosmetics that can cause hypersensitivity to ultraviolet (UV) radiation. Wear sunscreen with minimum SPF 15. Follow application guidelines which usually recommend applying liberally at least 20 min before exposure and repeating application every two hours or after getting out of the water or perspiring heavily. Wear wide brimmed hats, sunglasses with 100% UV protection, and tightly woven clothing that has high SPF.
	Hypothermia	Hypothermia, or severe decrease in body temperature, must be guarded against if work at the site takes place during temperatures below 65°F. Wear appropriate clothing in layers which provides better insulation than tight clothing which restricts blood flow. Make sure to protect the ears, face, hands and feet in extremely cold weather. Boots should be waterproof and insulated. Wear a hat; it will keep your whole body warmer. (Hats reduce the amount of body heat that escapes from your head.) Move into warm locations during work breaks; limit the amount of time outside on extremely cold days. Carry cold weather gear, such as extra socks, gloves, hats, jacket, blankets, a change of clothes and a thermos of hot liquid. Include a thermometer and chemical hot packs in your first aid kit. Avoid touching cold metal surfaces with bare skin. Monitor your physical condition and that of your coworkers.

Activity	Hazard(s)	Hazard Control/Mitigation
	Hyperthermia	Hyperthermia (also called heat stroke) is the result of significant overexposure to the factors of heat stress. Heat stroke is usually identified with a body temperature that increases to greater than 104°F. Symptoms are chills, irritability, hot and dry skin, convulsions leading to unconsciousness. Heat stroke is prevented by limiting or gradual increase (acclimation) of work load during extreme temperature conditions, take frequent breaks in shaded or cooled areas, and consume plenty of liquids prior to and during work activities.
	Severe weather including high winds/rain and thunder/lightening	Monitor weather forecasts and conditions. Avoid doing field work when thunder/lightening is expected. If storm is approaching, go to nearest large enclosed building. If caught out in open when thunder/lightening occurs, take shelter in vehicles with windows rolled up and do not touch metal surfaces.
	Hazardous flora/fauna, including spiders, wasps	Persons with allergic reactions to bee stings should inform the team lead and carry personal medication. Wear gloves while loading trailers, loading supplies, accessing compartments. Look before you reach.
	Sanitation hazards	An adequate supply of drinking water shall be provided on site. Cool water shall be provided during hot weather.
	Fatigue	Plan work to minimize fatigue. Take frequent breaks to avoid excessive fatigue. Get adequate rest the night before field activities.

Emergency Response:

For all emergencies that occur on USACE dams or adjacent property:

On the dam you must contact the dam Control Room first. Control Room personnel will initiate a 911 call, if necessary, and coordinate the required emergency response. When situation permits, call Single Point of Contact (**509-xxx-xxxx**) for Fire, Injury, Spill, and Vehicle Accident Reporting.

IHR Control Room: From a phone on the dam dial extension 231. From any other phone call (509) 543-3231.

For all emergencies that occur off USACE property:

First call 911, *then*, when emergency is stabilized, call the Single Point of Contact number at (509) xxx-xxxx for Fire, Injury, Spill, and Vehicle Accident Reporting.

Report events and conditions to the Single Point of Contact (509-xxx-xxxx) preferably within 30 minutes and notify management.

Nearest Hospital Locations:

Our Lady of Lourdes, 520 North 4th Ave, Pasco, WA 99301 (509) 547-7704

- From IHR – approximately 15 miles or 25 minutes

Nearest Hospital with Helipad:

Kennewick General Hospital, 900 S. Auburn, Kennewick, WA 99336, (509) 586-6111

- From IHR – approximately 16 miles via WA-124 or 30 minutes

For non-emergency events, contact:

Field Work Manager: Office (509) xxx-xxxx, Cellular (509) xxx-xxxx

Project Manager: Office (509) xxx-xxxx, Cellular (509) xxx-xxxx

Manager: Office Office (509) xxx-xxxx, Cellular (509) xxx-xxxx

S&H Representative: Office (509) xxx-xxxx, Cellular (509) xxx-xxxx

Operations Center: (509) xxx-xxxx

NOTE: If you need to make pen and ink changes to this plan or need clarification, contact your S&H Rep. 24/7.

Approval signature page: for project 11111- Multi-Year Biological Research at Ice Harbor Dam: Turbine

Characterization and Acoustic Telemetry Study			
Role	**Print Name**	**Signature**	**Date**
Project Manager			
Field Manager			
Office Manager			
S&H Rep			

Authorized Workers signature page: for project 11111- Multi-Year Biological Research at Ice Harbor Dam: Turbine Characterization and Acoustic Telemetry Study.

Authorized Workers

I have read the ES&H Plan, understand the hazards and controls associated with this work, and will implement the controls as indicated. I will inform the activity lead if there are changes to the hazards or if the controls appear to be inadequate.

Print Name	Signature	Date

Appendix B

Equipment

Appendix B

Equipment

A comprehensive equipment procurement list for the AT, turbine characterization, and bio-testing portions of the study are provided in Tables B.1-B.3.

Table B.1. List of equipment needed for one year of the AT portion of the Ice Harbor Turbine Evaluation Study. Some items have been procured by CENWW for other studies and may be available for use in this study; these items have been noted.

Item	Quantity	Size	Procurer	Procured Already (Y/N)	Comments
Cables	104		CENWW	Y	spares included
Y-blocks	28		CENWW	Y	spares included
Trolley sleds	39		CENWW	Y	spares included
Pipes	16		CENWW		
Cabled-array computers Systems	14		CENWW	Y	spares included
Hydrophones	56		CENWW	Y	spares included
Trolley beacon	10		CENWW	Y	spares included
Acoustic tags for study	5,940		CENWW		5,824 per year + 2% buffer to compensate for pre-release tag failure
PIT tags	5,882		CENWW		5,824 per year + 1% buffer to compensate for pre-release tag failure
Autonomous receivers	30		CENWW	Y	spares included

Acoustic releases	30	CENWW	Y	spares included
Release command unit	1	CENWW	Y	
Handheld GPS	3	CENWW	Y	
Baffles for hydrophones	56	Contractor		spares included
Auto receiver batteries	30	Contractor		rechargeable batteries
Auto receiver anchors	180	Contractor		spares included
Anchor buoy leads	180	Contractor		spares included
Computers (data processing)	3	Contractor		
Computer hard drives (internal)	40	Contractor		for up to 12 cable array systems
Trailers	4	Contractor		monthly rentals
Trailer power needs	4	Contractor		three 480-V transformer boxes, cables, contractor labor
Boats	1	Contractor		
Boat fuel		Contractor		
Boat maintenance	2	Contractor		for damaged props, motor and trailer servicing, etc.
Life jackets	5	Contractor		for boats
Tagging trailer	1	Contractor	Y	mobile tagging trailer, limited tagging space at JFF; CENWP owns a trailer that fits these needs but it's availability would need to be confirmed

Outside holding tanks	2	Contractor	Y	
Computer rack mounts	5	Contractor	Y	
Hard drive cases	20	Contractor	Y	
UPS/line conditioners	10	Contractor		
Misc. hardware/equipment		Contractor		
Circular tanks with lids (pre-surgery holding)	4	Contractor		30-in. × 30-in. circular; 4 tanks needed
Ethanol	10	Contractor		5 gallons
Sutures	56	Contractor		may be needed depending on surgery technique
UV sterilizers	3	Contractor	Y	
buckets square blue	100	Contractor	Y	
Surgery pads	1	Contractor		6-ft × 42-in. sheet; 8647K681
#11 surgical blades (incision method)	6,000	Contractor		
Microsharps	1,400	Contractor		only needed if single battery ATS transmitter is used
Microsharps handles	6	Contractor		need two per surgeon; only needed if single battery ATS transmitter is used
Forceps	6	Contractor		11152-10; need two more per surgeon; only needed if single battery ATS transmitter is used

Needle holders	6	Contractor		12002-14; need two more per surgeon; only needed if single battery ATS transmitter is used
Tupperware		Contractor		
Gloves	5	Contractor		19-149-863 or 19-048-132; 2000 gloves per box
Sodium bicarbonate	1	Contractor		SC12; 40-lb bucket
MS-222	3	Contractor		
Refrigerator for MS-222	1	Contractor	Y	
Argentyne	3	Contractor		Argent Labs
Chairs	4	Contractor		
Lamps	4	Contractor		
PIT-tag reader	2	Contractor	Y	Destron Fearing 2001F-ISO kit
Scale	1	Contractor	Y	
Laptop	1	Contractor		
Computer	1	Contractor		
Digitizer board	2	Contractor		
Digitizer pens	4	Contractor		
Poly-Aqua	1	Contractor		PA64; use DTpetsupplies.com if not available from AqEco
Sharps containers	10	Contractor		14-827-63; 3.06 1-gal 14-827-122 5-qt; 14-827-109 1-qt

Oxygen rental	3	Contractor		
DO meters	2	Contractor		YSI ProODO meter
pH meters	3	Contractor		YSI pH/Temp pen
Temperature loggers	12	Contractor		Hobo Water Temp Pro V2
DO/temp monitoring system	1	Contractor		
Storage trailer	2	Contractor		
Ice machine	1	Contractor	Y	
Fireproof safes	1	Contractor	Y	
Keyboards and mice	2	Contractor		2 sets - keyboard and mouse, Waterproof
Submersible pumps	3	Contractor		Flotec
Flex hose and fittings		Contractor		
Shade screen	4	Contractor		12-ft × 30-ft sections
Transport insulated totes	3	Contractor	Y	1 for each truck plus 1 extra
O_2 tank brackets	3	Contractor		
O_2 manifold	3	Contractor		
O_2 regulator	3	Contractor		1 per truck plus 1 extra; 5EFZ4
Invertors	4	Contractor		1 per truck plus 1 extra; hook into boat batteries
Bubblers	4	Contractor		Rena Air 400 or similar
Lights		Contractor		headlamps, spot lights

DO meter	6		Contractor	Y	3 meters for each of 2 transport trucks; YSI ProODO meter
Misc tagging equipment			Contractor		for broken or missing equipment
Injection pipe	1	4"X42'	CENWW		Sched 160
Injection pipe	1	4"X32.9'	CENWW		Sched 40
Injection pipe	1	4"X25.5'	CENWW		Sched 40
Electric sump pump	2	260 gpm	Contractor		Water supply for injection hose
Adjustable A frame gantry lift	1	1/2 ton	Contractor		Lower and lift sump pump
Electric winch	1	1/2 ton	Contractor		Attaches to gantry lift
Shackles	12	3/8"	Contractor		Stainless steel or galvanized
Depth sensor	2		Contractor		250 ft depth rating
Flex hose	300'	4"	Contractor		For 327' and 337' elev pipes
Flex hose	50'	2"	Contractor		From pump to injection tank
Flex hose	200'	2.5"	Contractor		For 314.5' elev pipe
Flex hose union	1	2.5"	Contractor		PVC
Flex hose union	2	4"	Contractor		PVC
2" pipe	1	6'	Contractor		PVC

45 deg fitting	1	3"	Contractor	PVC
Reducer fitting	3	3" to 2"	Contractor	PVC
Reducer fitting	2	3" to 2"	Contractor	PVC, male on 3" end
Reducer fitting	1	4" to 3"	Contractor	PVC
Quick fitting	1	2" to 3"	Contractor	PVC
Quick fitting	2	4"	Contractor	PVC
Quick fitting	1	2.5"	Contractor	PVC
Quick fitting	2	2"	Contractor	PVC
Ball valve	2	2"	Contractor	Brass
Cleanout with plug	1	3"	Contractor	PVC
Fish Injection Tank	1	120 L	Contractor	Poly
Hose clamps	50	5"	Contractor	
Hose clamps	25	3"	Contractor	
Pipe clamps	2	4"	Contractor	
Wire rope-SS	600	1/4"	Contractor	SS, need three sections at 150 ft each

Table B.2. List of equipment needed for one year of the turbine characterization portion of the Ice Harbor Turbine Evaluation Study. Some items have been procured by CENWW for other studies and may be available for use in this study; these items have been noted.

Item	Quantity	Size	Procurer	Already Procured (Y/N)	Comments
Injection pipe	1	4"X42'	CENWW		Sched 160
Injection pipe	1	4"X32.9'	CENWW		Sched 40
Injection pipe	1	4"X25.5'	CENWW		Sched 40
Electric sump pump	2	260 gpm	Contractor		Water supply for injection hose
Adjustable A frame gantry lift	1	1/2 ton	Contractor		Lower and lift sump pump
Electric winch	1	1/2 ton	Contractor		Attaches to gantry lift
Shackles	12	3/8"	Contractor		Stainless steel or galvanized
Depth sensor	2		Contractor		250 ft depth rating
Flex hose	300'	4"	Contractor		For 327' and 337' elev pipes
Flex hose	50'	2"	Contractor		From pump to injection tank
Flex hose	200'	2.5"	Contractor		For 314.5' elev pipe
Flex hose union	1	2.5"	Contractor		PVC
Flex hose union	2	4"	Contractor		PVC
2" pipe	1	6'	Contractor		PVC
45 deg fitting	1	3"	Contractor		PVC
Reducer fitting	3	3" to 2"	Contractor		PVC
Reducer fitting	2	3" to 2"	Contractor		PVC, male on 3" end
Reducer fitting	1	4" to 3"	Contractor		PVC
Quick fitting	1	2" to 3"	Contractor		PVC
Quick fitting	2	4"	Contractor		PVC
Quick fitting	1	2.5"	Contractor		PVC

Quick fitting	2	2"	Contractor		PVC
Ball valve	2	2"	Contractor		Brass
Cleanout with plug	1	3"	Contractor		PVC
Fish Injection Tank	1	120 L	Contractor		Poly
Hose clamps	50	5"	Contractor		
Hose clamps	25	3"	Contractor		
Pipe clamps	2	4"	Contractor		
Wire rope-SS	600	1/4"	Contractor		SS, need three sections at 150 ft each
Sensor Fish	80		Contractor		
Radio transmitters	80		CENWW	Y	164 to 168 MHz
Radio receivers	5		CENWW/Contract	Y	164 to 168 MHz
Radio antennas	5		CENWW	Y	164 to 168 MHz
Weights	2000	2.56 g	Contractor		
Balloon tags	2000	3/4"	Contractor		
Syringes	20	50 cc	Contractor		
Needles	50	22 gauge	Contractor		Pencil point needles
Laptop	3		Contractor		
Sensor Fish docking station	3		Contractor	Y	with USB cable
Sensor Fish Communicator software	1		Contractor	Y	
Magnets	64	5/8"X1/4"	Contractor		
Recovery modules	450		Contractor		
Atmospheric pressure logger	1		Contractor		

Table B.3. List of equipment needed for a one year of the bio-testing portion of the Ice Harbor Turbine Evaluation Study. Some items have been procured by CENWW for other studies and may be available for use in this study; these items have been noted.

Item	Quantity	Size	Procurer	Already Procured (Y/N)	Comments
Injection pipe	1	4"X42'	CENWW		Sched 160
Injection pipe	1	4"X32.9'	CENWW		Sched 40
Injection pipe	1	4"X25.5'	CENWW		Sched 40
Electric sump pump	2	260 gpm	Contractor		Water supply for injection hose
Adjustable A frame gantry lift	1	1/2 ton	Contractor		Lower and lift sump pump
Electric winch	1	1/2 ton	Contractor		Attaches to gantry lift
Shackles	12	3/8"	Contractor		Stainless steel or galvanized
Depth sensor	2		Contractor		250 ft depth rating
Flex hose	300'	4"	Contractor		For 327' and 337' elev pipes
Flex hose	50'	2"	Contractor		From pump to injection tank
Flex hose	200'	2.5"	Contractor		For 314.5' elev pipe
Flex hose union	1	2.5"	Contractor		PVC
Flex hose union	2	4"	Contractor		PVC
2" pipe	1	6'	Contractor		PVC
45 deg fitting	1	3"	Contractor		PVC
Reducer fitting	3	3" to 2"	Contractor		PVC
Reducer fitting	2	3" to 2"	Contractor		PVC, male on 3" end
Reducer fitting	1	4" to 3"	Contractor		PVC
Quick fitting	1	2" to 3"	Contractor		PVC
Quick fitting	2	4"	Contractor		PVC
Quick fitting	1	2.5"	Contractor		PVC

Quick fitting	2	2"	Contractor		PVC
Ball valve	2	2"	Contractor		Brass
Cleanout with plug	1	3"	Contractor		PVC
Fish Injection Tank	1	120 L	Contractor		Poly
Hose clamps	50	5"	Contractor		
Hose clamps	25	3"	Contractor		
Pipe clamps	2	4"	Contractor		
Wire rope-SS	600	1/4"	Contractor		SS, need three sections at 150 ft each
Sensor Fish	TBD		Contractor		Dependent on sample sizes
Radio transmitters	80		CENWW	Y	164 to 168 MHz
Radio receivers	5		CENWW/Contract	Y	164 to 168 MHz
Radio antennas	5		CENWW	Y	164 to 168 MHz
Weights	TBD	2.56 g	Contractor		Dependent on sample sizes
Balloon tags	TBD	3/4"	Contractor		Dependent on sample sizes
Syringes	20	50 cc	Contractor		
Needles	50	22 gauge	Contractor		Pencil point needles
Laptop	3		Contractor		
Sensor Fish docking station	3		Contractor	Y	with USB cable
Sensor Fish Communicator software	1		Contractor	Y	
Magnets	64	5/8"X1/4"	Contractor		
Recovery modules	450		Contractor		
Atmospheric pressure logger	1		Contractor		
Tagging supplies	TBD		Contractor		Dependent on sample sizes
Circular holding tanks	6		Contractor		Pre- and post-treatment holding

Buckets	TBD	5 gallon	Contractor	Dependent on sample sizes

Appendix C

Hydraulic Extent Detail

Appendix C

Hydraulic Extent Details

The hydraulic extent of IHR is defined as the area of hydraulic influence related to project operations in the forebay (upstream) and tailrace (downstream; Rakowski et al. 2010). It represents the area in which project operations are the primary factor influencing the velocity and flow direction for typical fish passage flows.

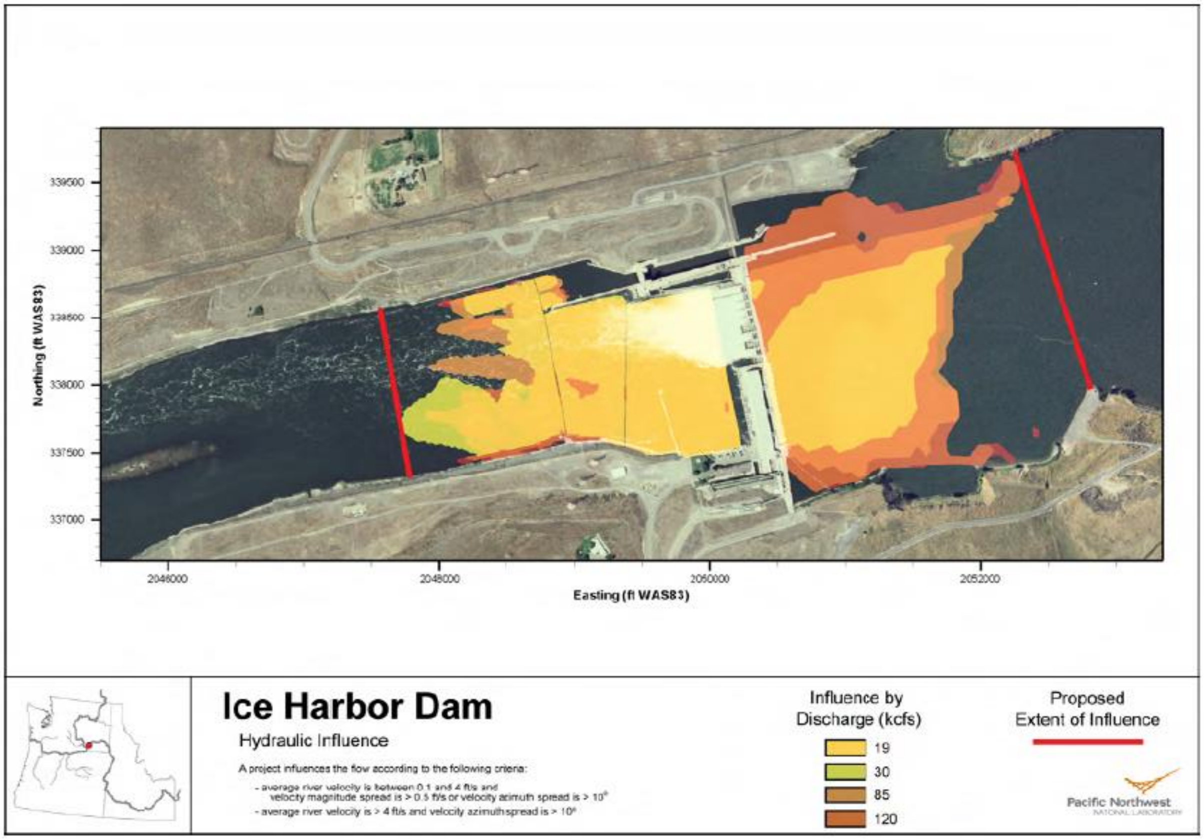


Figure C.1. Hydraulic influence of IHR, showing the proposed extent of influence (red).

Appendix D

Maps and Coordinates of Autonomous Receiver Arrays

Appendix D

Maps and Coordinates of Autonomous Receiver Arrays

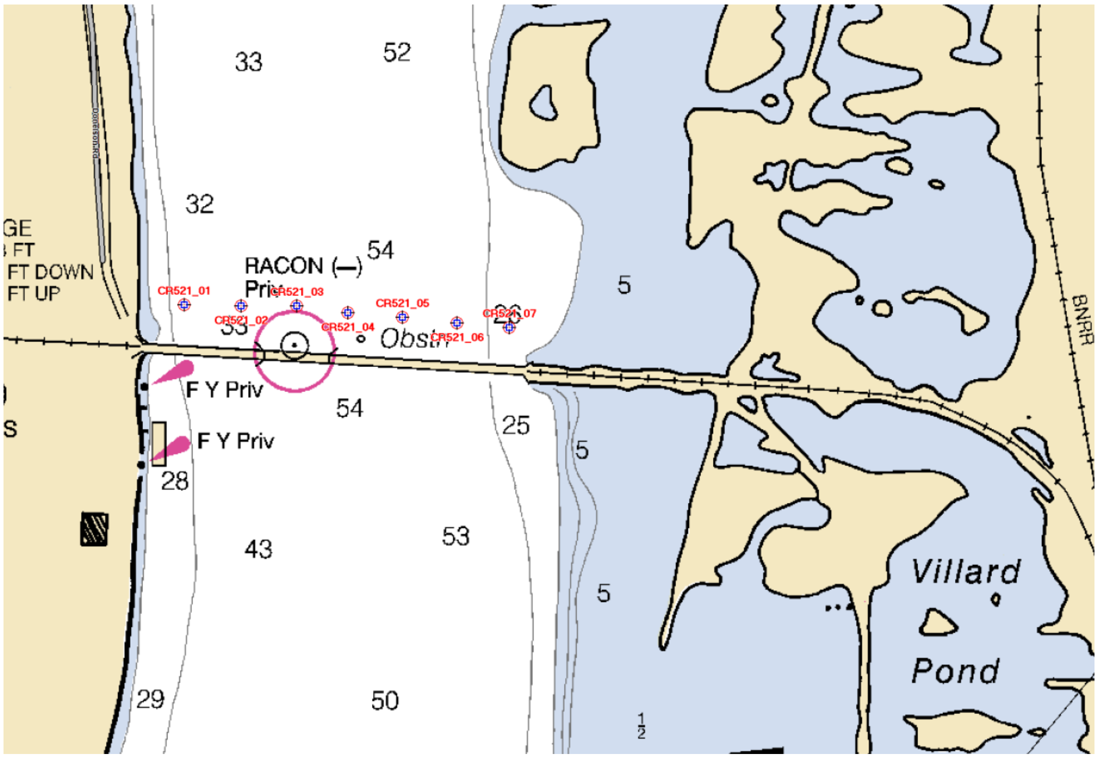


Figure D.1. Fugawi marine map of survival D1 array with seven autonomous receiver waypoints (red square icons) at CR521, about 18 km downstream of IHR.

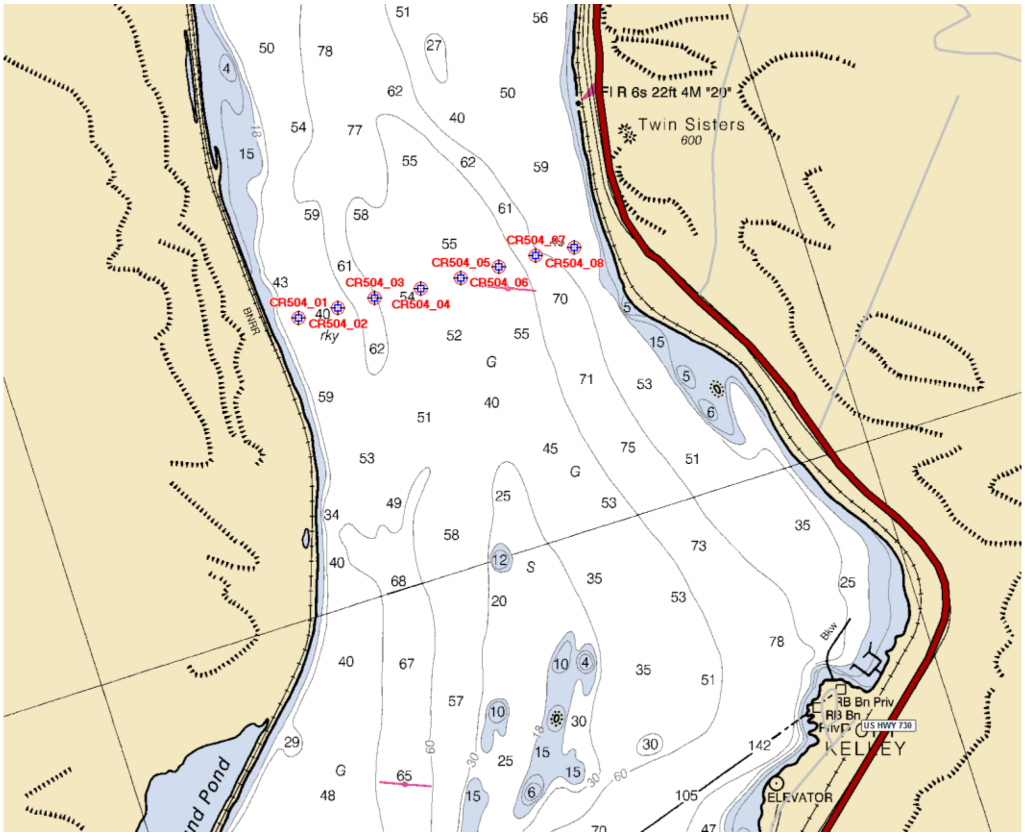


Figure D.2. Fugawi marine map of the D2 autonomous receiver array at CR504, about 34 km upstream of McNary Dam. This array will have eight receivers, as indicated by red and blue circle icons.

Table D.1. List of waypoint names and coordinates of proposed autonomous receiver sites for an IHR turbine evaluation study. The waypoint name is a concatenation of CR for Columbia River with river km to indicate array location, and with _##, to indicate receiver position within the array from river bank right to river bank left (when facing downstream). The datum for latitudes and longitudes was WGS84.

Autonomous Receiver Waypoints		
Waypoint Name	Latitude	Longitude
CR521_01	46.1774985	-119.0213122
CR521_02	46.1780595	-119.0203018
CR521_03	46.1786228	-119.0193279
CR521_04	46.1790573	-119.0183342
CR521_05	46.1795539	-119.0173139
CR521_06	46.1800366	-119.0162771
CR521_07	46.1805102	-119.0152966
CR504_01	46.0430495	-118.9541504
CR504_02	46.0427634	-118.9525171
CR504_03	46.0424897	-118.9507694
CR504_04	46.0422207	-118.9491282
CR504_05	46.0419126	-118.9473962
CR504_06	46.0416608	-118.9457472
CR504_07	46.0413691	-118.9440891
CR504_08	46.0410712	-118.9424882

Appendix E

Fish Collection, Tagging, and Release Schedule

Appendix E

Fish Collection, Tagging, and Release Schedule

Table E.1. Example fish release schedule for yearling Chinook salmon by release time. Numbers of yearling Chinook salmon to be collected, tagged, and released by date, release type, and time of day in the spring of 2017. Release types and times are color coded to indicate the release time. Day and night releases are indicated by a D or N.

			Collect	Tag	Release			
Day Count	Date	Time			R1	R2	R3	Dead
1	4/26/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	173					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						
2	4/27/2017	0						
		1						
		2						
		3						
		4						
		5						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		173				
		18						
		19						
		20						
		21						
		22						
		23						
3	4/28/2017	0						
		1						
		2						
		3						
		4						
		5			1-R1N-CH1	1-R2N-CH1	1-R3N-CH1	1-MSN-CH1
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	170					
		16						
		17						
		18						
		19						

Day Count	Date	Time	Collect	Tag	Release R1	R2	R3	Dead
		20						
		21						
		22						
		23						
4	4/29/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
5	4/30/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		11			2-R1D-CH1	2-R2D-CH1	2-R3D-CH1	2-MSD-CH1
		12						
		13						
		14						
		15	170					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						
6	5/1/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
7	5/2/2017	0						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	170					
		16						
		17			3-R1D-CH1	3-R2D-CH1	3-R3D-CH1	3-MSD-CH1
		18						
		19						
		20						
		21						
		22						
		23						
8	5/3/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						

Day Count	Date	Time	Collect	Tag	Release			
					R1	R2	R3	Dead
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
9	5/4/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	170					
		16						
		17						
		18						
		19						
		20						
		21			4-R1N-CH1	4-R2N-CH1	4-R3N-CH1	4-MSN-CH1
		22						
		23						
10	5/5/2017	0						
		1						
		2						
		3						
		4						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
11	5/6/2017	0						
		1						
		2						
		3						
		4						
		5			5-R1N-CH1	5-R2N-CH1	5-R3N-CH1	5-MSN-CH1
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	173					
		16						
		17						
		18						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		19						
		20						
		21						
		22						
		23						
12	5/7/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		173				
		18						
		19						
		20						
		21						
		22						
		23						
13	5/8/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		10						
		11			6-R1D-CH1	6-R2D-CH1	6-R3D-CH1	6-MSD-CH1
		12						
		13						
		14						
		15	170					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						
14	5/9/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
15	5/10/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	170					
		16						
		17			7-R1D-CH1	7-R2D-CH1	7-R3D-CH1	7-MSD-CH1
		18						
		19						
		20						
		21						
		22						
		23						
16	5/11/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Dead
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
17	5/12/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	170					
		16						
		17						
		18						
		19						
		20						
		21			8-R1N-CH1	8-R2N-CH1	8-R3N-CH1	8-MSN-CH1
		22						
		23						
18	5/13/2017	0						
		1						
		2						
		3						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
19	5/14/2017	0						
		1						
		2						
		3						
		4						
		5			9-R1N-CH1	9-R1N-CH1	9-R3N-CH1	9-MSN-CH1
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	170					
		16						
		17						

Day Count	Date	Time	Collect	Tag	Release R1	R2	R3	Dead
		18						
		19						
		20						
		21						
		22						
		23						
20	5/15/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
21	5/16/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		9						
		10						
		11			10-R1D-CH1	10-R2D-CH1	10-R3D-CH1	10-MSD-CH1
		12						
		13						
		14						
		15	173					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						
22	5/17/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		173				
		18						
		19						
		20						
		21						
		22						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		23						
23	5/18/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	170					
		16						
		17			11-R1D-CH1	11-R2D-CH1	11-R3D-CH1	11-MSD-CH1
		18						
		19						
		20						
		21						
		22						
		23						
24	5/19/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
25	5/20/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	170					
		16						
		17						
		18						
		19						
		20						
		21			12-R1N-CH1	12-R2N-CH1	12-R3N-CH1	12-MSN-CH1
		22						
		23						
26	5/21/2017	0						
		1						
		2						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
27	5/22/2017	0						
		1						
		2						
		3						
		4						
		5			13-R1N-CH1	13-R2N-CH1	13-R3N-CH1	13-MSN-CH1
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	170					
		16						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		17						
		18						
		19						
		20						
		21						
		22						
		23						
28	5/23/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
29	5/24/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		8						
		9						
		10						
		11			14-R1D-CH1	14-R2D-CH1	14-R3D-CH1	14-MSD-CH1
		12						
		13						
		14						
		15	170					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						
30	5/25/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		22						
		23						
31	5/26/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	173					
		16						
		17			15-R1D-CH1	15-R2D-CH1	15-R3D-CH1	15-MSD-CH1
		18						
		19						
		20						
		21						
		22						
		23						
32	5/27/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		12						
		13						
		14						
		15						
		16						
		17		173				
		18						
		19						
		20						
		21						
		22						
		23						
33	5/28/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17						
		18						
		19						
		20						
		21			16-R1N-CH1	16-R2N-CH1	16-R3N-CH1	16-MSN-CH1
		22						
		23						

Table E.2. Example fish release schedule for yearling Chinook salmon by release time. Numbers of subyearling Chinook salmon to be collected, tagged, and released by date, release type, and time of day in the summer of 2017. Release types and times are color coded to indicate the release time. Day and night releases are indicated by a D or N.

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
1	5/30/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	194					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						
2	5/31/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						

Day Count	Date	Time	Collect	Tag	Release R1	R2	R3	Dead
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		194				
		18						
		19						
		20						
		21						
		22						
		23						
3	6/1/2017	0						
		1						
		2						
		3						
		4						
		5			1-R1N-CH0	1-R2N-CH0	1-R3N-CH0	1-MSN-CH0
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	194					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
4	6/2/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		194				
		18						
		19						
		20						
		21						
		22						
		23						
5	6/3/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11			2-R1D-CH0	2-R2D-CH0	2-R3D-CH0	2-MSD-CH0
		12						
		13						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		14						
		15	194					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						
6	6/4/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
7	6/5/2017	0						
		1						
		2						
		3						
		4						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	191					
		16						
		17			3-R1D-CH0	3-R2D-CH0	3-R3D-CH0	3-MSD-CH0
		18						
		19						
		20						
		21						
		22						
		23						
8	6/6/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		19						
		20						
		21						
		22						
		23						
9	6/7/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	194					
		16						
		17						
		18						
		19						
		20						
		21			4-R1N-CH0	4-R2N-CH0	4-R3N-CH0	4-MSN-CH0
		22						
		23						
10	6/8/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
11	6/9/2017	0						
		1						
		2						
		3						
		4						
		5			5-R1N-CH0	5-R2N-CH0	5-R3N-CH0	5-MSN-CH0
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	194					
		16						
		17						
		18						
		19						
		20						
		21						
		22						

Day Count	Date	Time	Collect	Tag	Release R1	R2	R3	Dead
		23						
12	6/10/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		173				
		18						
		19						
		20						
		21						
		22						
		23						
13	6/11/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11			6-R1D-CH0	6-R2D-CH0	6-R3D-CH0	6-MSD-CH0
		12						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		13						
		14						
		15	191					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						
14	6/12/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
15	6/13/2017	0						
		1						
		2						
		3						

Day Count	Date	Time	Collect	Tag	Release			
					R1	R2	R3	Dead
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	194					
		16						
		17			7-R1D-CH0	7-R2D-CH0	7-R3D-CH0	7-MSD-CH0
		18						
		19						
		20						
		21						
		22						
		23						
16	6/14/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				

Day Count	Date	Time	Collect	Tag	Release			
					R1	R2	R3	Dead
		18						
		19						
		20						
		21						
		22						
		23						
17	6/15/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	194					
		16						
		17						
		18						
		19						
		20						
		21			8-R1N-CH0	8-R2N-CH0	8-R3N-CH0	8-MSN-CH0
		22						
		23						
18	6/16/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
19	6/17/2017	0						
		1						
		2						
		3						
		4						
		5			9-R1N-CH0	9-R1N-CH0	9-R3N-CH0	9-MSN-CH0
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	191					
		16						
		17						
		18						
		19						
		20						
		21						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		22						
		23						
20	6/18/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
21	6/19/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11			10-R1D-CH0	10-R2D-CH0	10-R3D-CH0	10-MSD-CH0

			Collect	Tag	Release			
Day Count	Date	Time			R1	R2	R3	Dead
		12						
		13						
		14						
		15	194					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						
22	6/20/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		173				
		18						
		19						
		20						
		21						
		22						
		23						
23	6/21/2017	0						
		1						
		2						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	194					
		16						
		17			11-R1D-CH0	11-R2D-CH0	11-R3D-CH0	11-MSD-CH0
		18						
		19						
		20						
		21						
		22						
		23						
24	6/22/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
25	6/23/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	191					
		16						
		17						
		18						
		19						
		20						
		21			12-R1N-CH0	12-R2N-CH0	12-R3N-CH0	12-MSN-CH0
		22						
		23						
26	6/24/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						

Day Count	Date	Time	Collect	Tag	Release			
					R1	R2	R3	Dead
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
27	6/25/2017	0						
		1						
		2						
		3						
		4						
		5			13-R1N-CH0	13-R2N-CH0	13-R3N-CH0	13-MSN-CH0
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	194					
		16						
		17						
		18						
		19						
		20						

Day Count	Date	Time	Collect	Tag	Release R1	R2	R3	Dead
		21						
		22						
		23						
28	6/26/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
29	6/27/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11			14-R1D-	14-R2D-	14-R3D-	14-MSD-

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
					CH0	CH0	CH0	CH0
		12						
		13						
		14						
		15	194					
		16						
		17						
		18						
		19						
		20						
		21						
		22						
		23						
30	6/28/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17		170				
		18						
		19						
		20						
		21						
		22						
		23						
31	6/29/2017	0						
		1						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15	194					
		16						
		17			15-R1D-CH0	15-R2D-CH0	15-R3D-CH0	15-MSD-CH0
		18						
		19						
		20						
		21						
		22						
		23						
32	6/30/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						

Day Count	Date	Time	Collect	Tag	Release R1	Release R2	Release R3	Release Dead
		16						
		17		173				
		18						
		19						
		20						
		21						
		22						
		23						
33	7/1/2017	0						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		11						
		12						
		13						
		14						
		15						
		16						
		17						
		18						
		19						
		20						
		21			16-R1N-CH0	16-R2N-CH0	16-R3N-CH0	16-MSN-CH0
		22						
		23						

Appendix F

Acoustic Telemetry Data Management

Appendix F

Acoustic Telemetry Data Management

Numerous data are collected and managed for the successful analysis of AT survival studies. Information collected during the fish tagging and release component of data management is provided in Table F.1.

Table F.1. Variable Names, Formats, and Descriptions for Fish Tagging and Release Data. Variables in bold are key fields and must be a unique combination for each entry. Hours in date/time variables will be in PDT during processing to create this data set.

Variable Name	Format	Description
tag_code	Char	Acoustic-tag code
project_code	Char	Code to indicate study responsible for fish release
tag_group	Char	A code to distinguish between analysis groups
tagger_name_xlat	Char	Unique identifier for each tagger
bucket	Numeric	Sequential number for each release location
lot	Numeric	Manufacturing lot of tags
species_code_xlat	Char	Species code identifier following the PTAGIS scheme: yearling Chinook salmon = "11U"; subyearling Chinook salmon = "13U"
length	Numeric	Fork length to the nearest mm(###)
weight	Numeric	Weight (g) to the nearest 0.1 g (###.#)
PIT_code(a)	Char	PIT-tag code
tag_year	Numeric	Year of tagging
fish_tag_date	yyyy-mm-dd hh:mm:ss	Fish tagging date/time
tag_activate_date	yyyy-mm-dd hh:mm:ss	Tag-activation date/time
tag_release_date	yyyy-mm-dd hh:mm:ss	Tag-release date/time
release_location	Char	Nominal release location
release_location_xlat	Char	Release sublocation indicating point of release across the river channel
release_location_river_kilometer	Numeric	River kilometer from the mouth of the Columbia River
release_location_latitude	Decimal degrees	Latitude of release location
release_location_longitude	Decimal degrees	Longitude of release location
mort_xlat	Numeric	0=alive; 1=dead; 2=intentionally sacrificed; (#)
pri	Numeric	Nominal pulse repetition interval

(a) PIT-tag marking codes are obtained from the *2009 PIT-Tag Specification Document (Pacific States Marine Fisheries Commission 2009).*

Data files identifying location and time parameters associated with node deployment and sampling conclusions are shown in Table F.2.

Table F.2. Variable Names, Formats, and Descriptions for Receiver Deployment Data. Variables in bold are key fields and must be a unique combination for each entry. Hours in date/time variables will be in PDT during processing to create this data set.

Variable Name	Format	Description

node_code	Char	A unique code incorporating the receiver serial number and the date of deployment
project_code	Char	Project responsible for deploying this receiver
Latitude	Decimal degrees	Latitude of receiver location
Longitude	Decimal degrees	Longitude of receiver location
river_kilometer	Numeric	River kilometer from the mouth of the Columbia River
location	Char	Array location designation (e.g., CR349.0)
location_xlat	Char	Receiver location designation (e.g., CR349.0+01)
deploy_date	yyyy-mm-dd hh:mm:ss	Time when receiver began sampling
deploy_year	Numeric	Year of deployment
recovery_date	yyyy-mm-dd hh:mm:ss	Time when receiver stopped sampling
elev_or_depth	Numeric	Depth of autonomous nodes (nearest foot) or elevation in feet above mean sea level for dam-mounted hydrophones (e.g., 67.27)

Detection event data is gathered by filtering JSATS tag codes within the raw receiver data files to summarize individual detections (Table F.3).

Table F.3. Variable Names, Formats, and Descriptions for Detection Event Data. Variables in bold are key fields and must be a unique combination for each entry. Hours in date/time variables will be in PDT during processing to create this data set.

Variable Name	Format	Description
node_code	Char	A unique code incorporating the receiver serial number and the date of deployment (####_yymmdd)
tag_code	Char	Acoustic-tag code
first_computed_datetime	yyyy-mm-dd hh:mm:ss	Date/time of first hit
last_computed_datetime	yyyy-mm-dd hh:mm:ss	Date/time of last hit
hits	Numeric	Number of individual hits included in this event

Filters are applied to the raw receiver data files to remove detections related to background noise. The following three filters are used:

Multipath filter: For data from each individual receiver or hydrophone, delete all tag code receptions that occur within 0.156 seconds after an initial identical tag code reception under the assumption that closely lagging signals are multipath. Initial code receptions are retained. The delay of 0.156 seconds is the maximum acceptance window width for evaluating a pulse repetition interval (PRI) and is computed as 2(PRI_Window+12×PRI_Increment). Both PRI_Window and PRI_Increment are currently set at 0.006, which was chosen to be slightly larger than the potential rounding error in estimating PRI to two decimal places.

Multi-detection filter (cabled arrays only): Retain receptions only if the same tag code was received at another hydrophone in the same array within 0.3 seconds because receptions on separate hydrophones within 0.3 seconds (about 450 m of range) are likely from a single tag transmission.

PRI filter. Retain only those series of receptions of a tag code (or "hits") that are consistent with the pattern of transmissions from a properly functioning JSATS acoustic-tag. Filtering rules are evaluated for each tag code individually, and it is assumed that only a single tag will be transmitting that code at any given time. For a cabled system, the PRI filter operates on a message, which includes all receptions of the same transmission on multiple hydrophones within 0.3 seconds. Each autonomous receiver is processed independently, so each hit represents a message. Message time is defined as the earliest reception time across all hydrophones for that message. Detection requires that at least four (autonomous) or six (cabled) messages are received with an appropriate time interval between the leading edges of successive messages. The processing steps are as follows:

a. For each message, select the list of messages that follow within [(Nominal_PRI×1.3×12)+1] seconds. The list of Nominal_PRI by tag code must be available as an input and typically is obtained from the tag manufacturer.

b. Compute a list of candidate PRIs as follows:

$$Candidate\ PRI\ list = \prod_{i=1}^{12} \frac{(Time_{hit} - Time_{Initial\ Hit})}{i}$$

where *i* is a counter that steps through the 12 possible PRI intervals that can fit between the initial message and the end of the time window described in Step a. Round each candidate PRI to the nearest hundredth of a second and exclude candidate PRIs < Nominal_PRI × 0.651 or > Nominal_PRI × 1.3 from the list. These coefficients were chosen to result in a range of candidate PRIs that do not include multiples of any other candidates in the list. Avoiding exact multiples in the candidate PRI list simplifies the process of identifying a mode.

c. Take the minimum mode of the list of candidate PRIs from Step b as the estimate of PRI to be used in building an event associated with the initial message. If no mode exists, use the minimum candidate PRI as the estimate of PRI.

d. Add messages to the accepted list if their time interval from the initial message falls within narrow bounds around even multiples of the estimated PRI from the initial hit. An acceptance window is defined by:

   Acceptance window= $i(Estimated\_PRI) \pm \left[PRI\_Window + i\left(PRI\_Iincrement\right)\right]$,

   where PRI_Window = 0.006; PRI_Increment = 0.006, as described in Step a; and *i* is the PRI interval obtained by rounding (Cumulative seconds/Estimated PRI) to an integer, where cumulative seconds elapsed are measured from the initial hit in a series.

e. Create a detection event if at least four (autonomous) or six (cabled) accepted messages remain (including the initial message).

f. Select the first message after the initial message as the new initial message, and repeat Steps a through e above until all messages have been processed.

g. Combine any two or more detection events that overlap in time into a single detection event.

h. Repeat Steps a through g for each tag code.

Once the filters have been applied the result is a clean cabled array data set. The variables of a clean cabled array data set and their descriptions are presented in Table F.4.

Table F.4. Variable names, lengths, types, and descriptions in clean cabled array data set.

Variable Name	Lengths	Format	Description
ACTAGCODE	9	Char	Acoustic-tag code
H_ID	9	Char	Concatenation (‖) of "I" for IHR ‖ "P" for powerhouse or "S" for spillway ‖ "T" for turbine, "S" for sluice, "B" for bay, or "_" for missing ‖ "##_##" which designates a pier or a numeric sequence for bank or forebay hydrophones ‖ "D" for deep or "S" for shallow. For piers, the first ## indicates a lower number for an adjacent turbine or spillbay and the second ## indicates the higher number designating the other adjacent turbine or spillbay. Every H_ID will have a corresponding H_LAT, H_LON, and H_Z. IHR examples include IPT01_02D, IPS00_01S, IPS01_02S, ISB01_02D, ISB17_18S
H_LAT	10	Decimal degrees	Hydrophone latitude
H_LON	12	Decimal degrees	Hydrophone longitude
H_Z	3	Numeric	Hydrophone depth (m)
ARRAY	5	Char	Concatenation of river and river kilometer (e.g., SR067)
EVENT_ID	8	Numeric	PRI filter event count
HIT_CNT	4	Numeric	Count of decoded receptions in a series that pass all filtering criteria (# to ####)
HIT_TIME	20	yyyy-mm-dd hh:mm:ss	Date and time of hit
SECONDS	17	Numeric	Relative time in seconds since some reference date and time

A clean detection data set is the result of the tagging and release data set and the detection data sets being merged. It contains valid detection events for all detection locations. Each entry is a single event for a unique single acoustic-tag observation and contains all variables associated with tagging, release, and detection, including the receiver latitude, longitude, and depth (Table F.5).

Table F.5. Variable names, lengths, types, and descriptions in clean detection data set. This archival data set can be used in the future to reconstruct capture histories or to examine detection processes for secondary uses by the CENWW. All hours in date/time variables will be in PDT. This data set may contain live- and dead fish detections (MORT=0, 1, or 2).

Variable Name	Length	Format	Description
Season	6	Char	Assigned based on release date and time
species_code_xlat	3	Char	Species code identifier following the PTAGIS scheme: yearling Chinook salmon = "11U"; subyearling Chinook salmon = "13U"
Sp	8	Char	Yearling Chinook salmon = "SPR_CHN"; Subyearling Chinook salmon = "FALL_CHN"
Length	3	Numeric	Fork length to the nearest mm (###)
Weight	5	Numeric	Weight (g) to the nearest 0.1 g (###.#)
Clip	2	Char	Fin clip indication ("AD" = adipose clipped; "AI" = adipose intact)

Variable Name	Length	Format	Description
Rel_Loc	6	Char	Release location (e.g., SR040R, SR015R, CR521R)
Rel_PT	1	Numeric	Release point from 1 to 6 (#) from the north shore (river right) to the south shore (river left) in the lower Snake River
Bucket	2	Numeric	Sequential number for each REL_LOC (##)
Tag_Date	8	yyyy-mm-dd	Date of tagging
RDateTime	14	yyyy-mm-dd hh:mm:ss	Date/time of release
ADateTIme	14	yyyy-mm-dd hh:mm:ss	Date/time of tag-activation
Tagger	6	Char	Unique identifier for each tagger
PIT	14	Char	PIT-tag code
mort_xlat	1	Numeric	0=alive; 1=dead; 2=intentionally sacrificed; (#)
ACTAGCODE	9	Char	Acoustic-tag code (common variable)
PRI	2	Numeric	Nominal PRI
Node_ID	11	Char	A unique code incorporating the reciver serial number and the date of deployment (####_yymmdd)
N_Loc	10	Char	SR###_##, where ### is river km and ## is receiver number (from N to S, river right to left) in an array
N_Lat	10	Decimal degrees	Latitude of receiver location
N_Lon	12	Decimal degrees	Longitude of receiver location
N_Z	3	Numeric	Receiver depth (m)
H_ID	9	Char	Concatenation (‖) of "I" for IHR ‖ "P" for powerhouse or "S" for spillway ‖ "T" for turbine, "S" for sluice, "B" for bay, or "_" for missing ‖ "##_##" which designates a pier or a numeric sequence for bank or forebay hydrophones ‖ "D" for deep or "S" for shallow. For piers, the first ## indicates a lower number for an adjacent turbine or spillbay and the second ## indicates the higher number designating the other adjacent turbine or spillbay. Every H_ID will have a corresponding H_LAT, H_LON, and H_Z. IHR examples include IPT01_02D, IPS00_01S, IPS01_02S, ISB01_02D, ISB17_18S
H_Lat	10	Decimal degrees	Latitude of hydrophone specified by H_ID
H_Lon	12	Decimal degrees	Longitude of hydrophone specified by H_ID
H_Z	3	Numeric	Depth of hydrophone specified by H_ID
Array	5	Char	Concatenation of river and river kilometer (e.g., SR017 = rkm 17 on the Snake River)
Event_ID	8	Numeric	PRI filter event count
Hit_Cnt	4	Numeric	Count of decoded receptions in a series that pass all filtering criteria (# to ####)
Hit_Time	20	mm/dd/yy hh:mm:ss:##	Date/time within 0.01s of the reception time
Seconds	13	Numeric	Relative time in seconds since some reference date and time

Appendix G

Sensor Fish Injection System

Appendix G

Sensor Fish Injection System

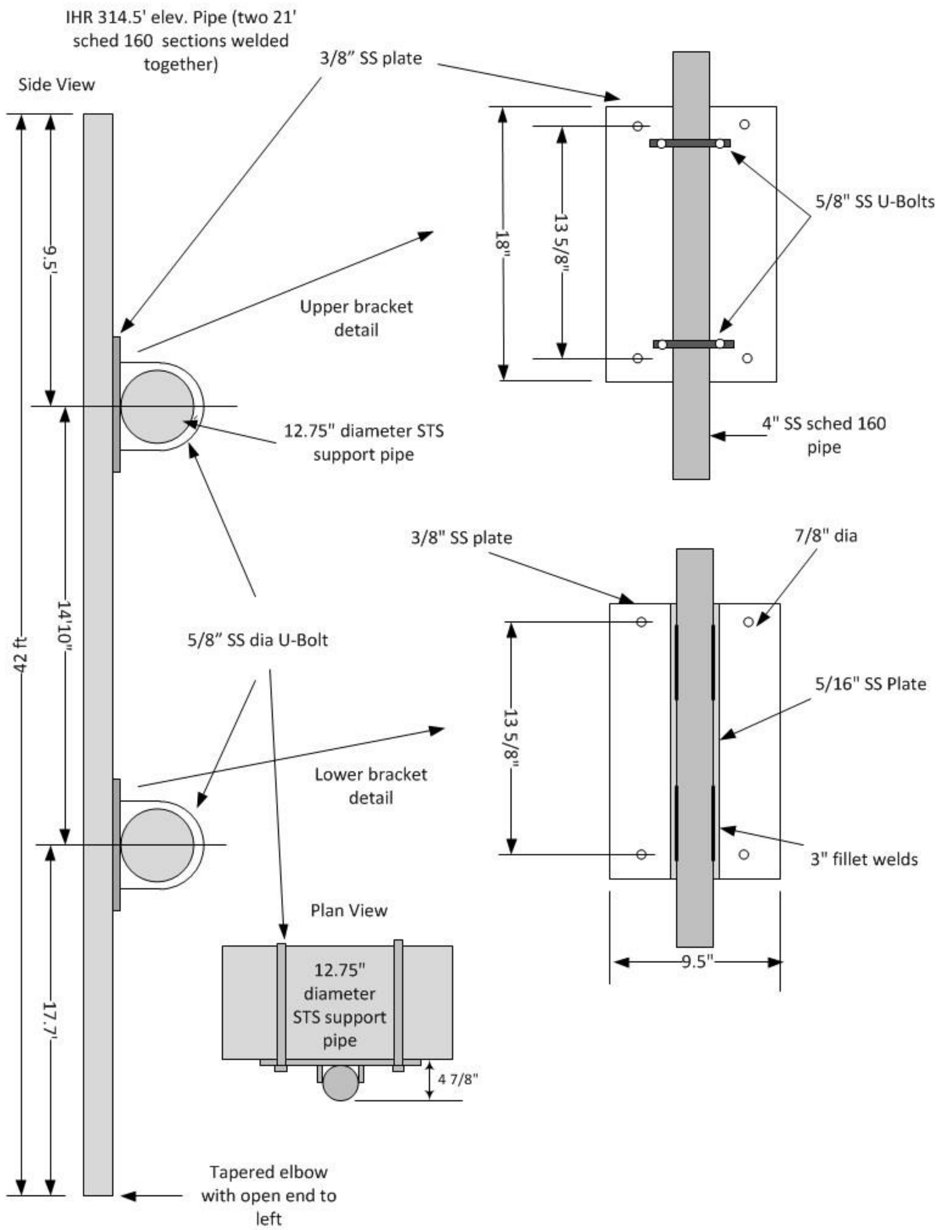


Figure G.1. Concept drawings of the 314.5-ft elevation injection pipe showing dimensions and associated hardware.

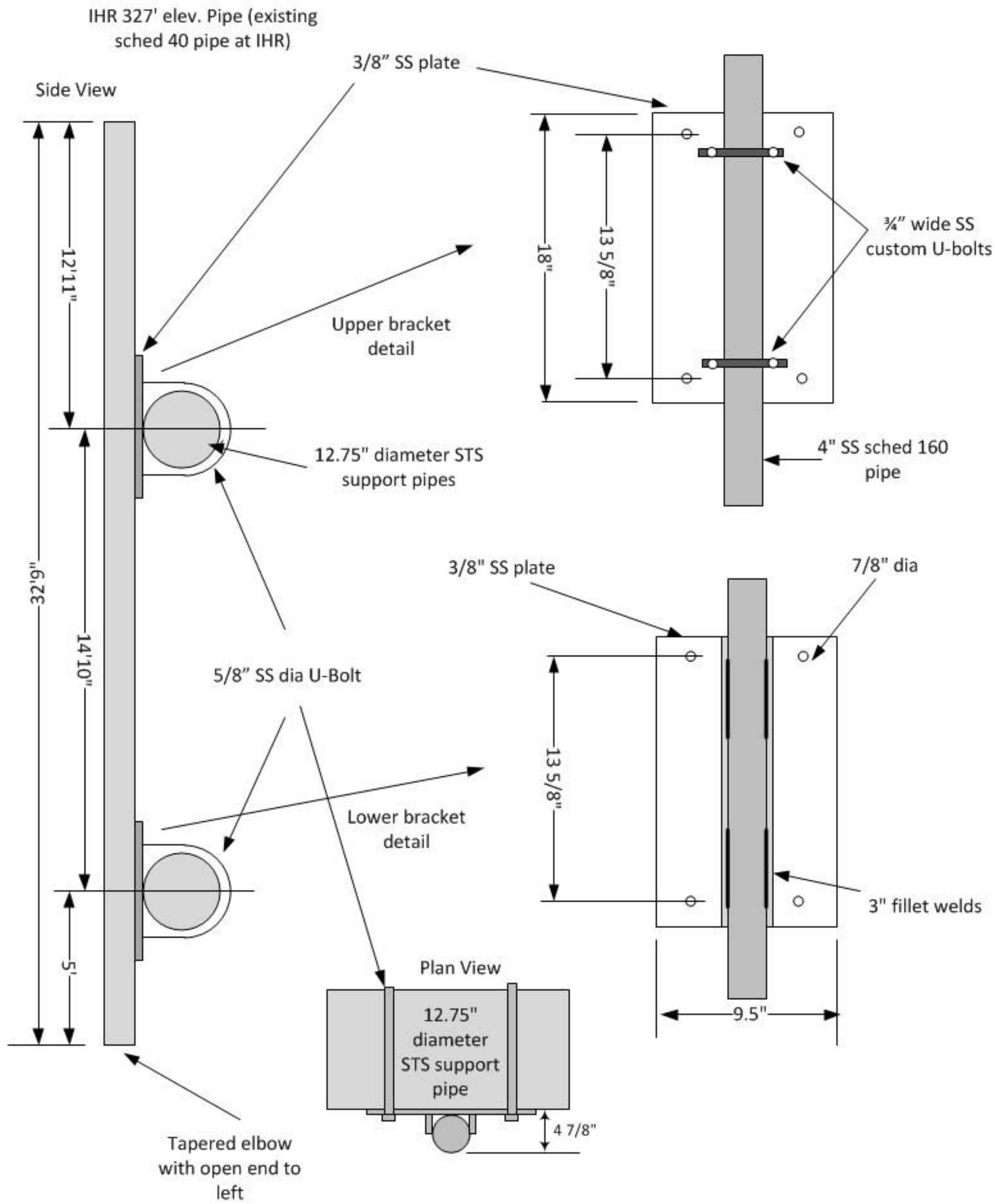


Figure G.2. Concept drawings of the 327-ft elevation injection pipe showing dimensions and associated hardware.

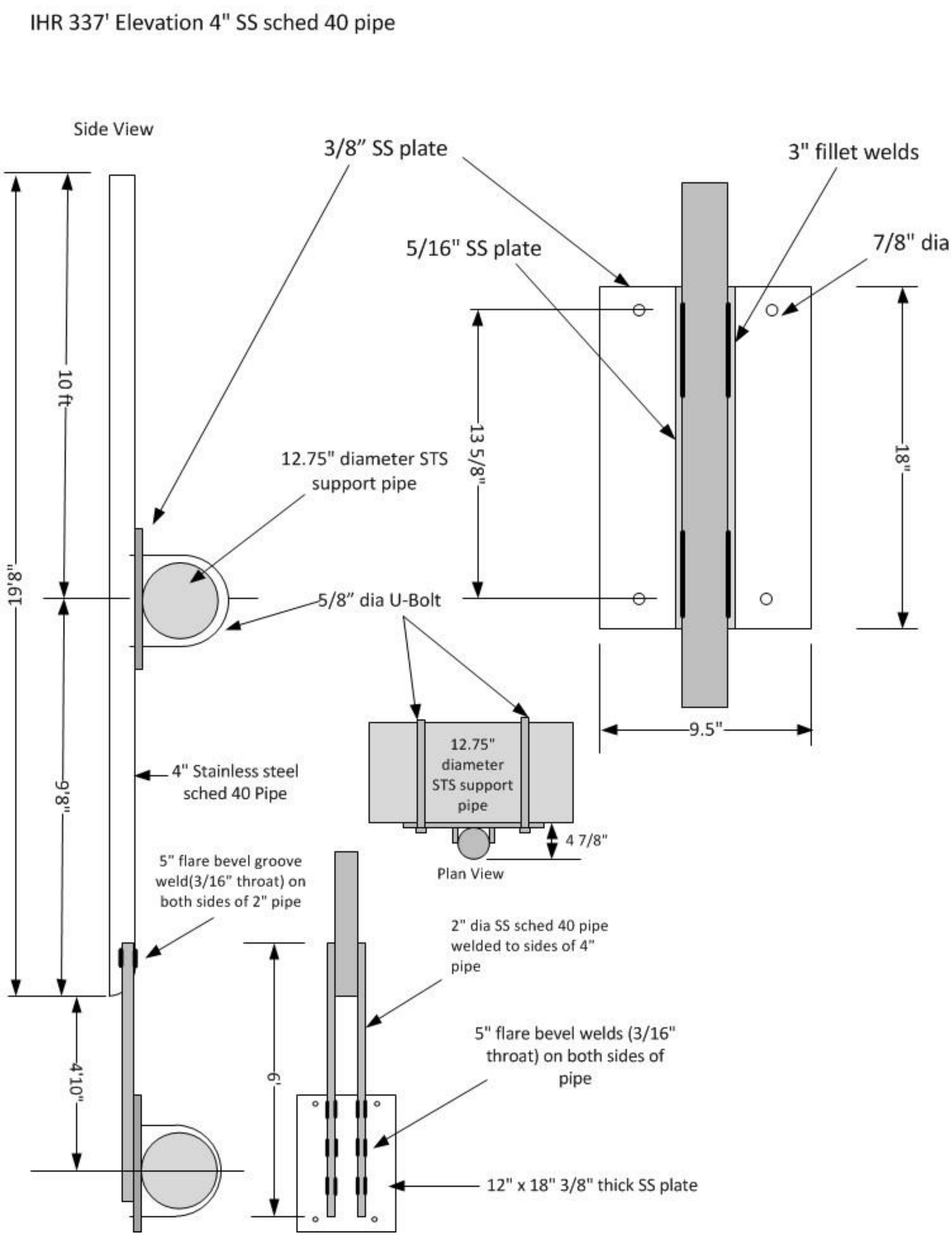


Figure G.3. Concept drawings of the 337-ft elevation injection pipe showing dimensions and associated hardware.

Appendix H

Ice Harbor Dam Boat Restricted Zone Policy

Appendix H

Ice Harbor Dam Boat Restricted Zone Policy

1. PURPOSE. This Standard Operating Procedure (SOP) outlines the appropriate policies, procedures, and responsibilities to ensure personnel working in restricted zones are fully apprised of the hazards associated with the structures, current operating conditions, and required safety equipment.

2. APPLICABILITY. The BRZ policy is applicable to personnel or equipment entering the BRZ at Ice Harbor Lock and Dam.

3. INFORMATION. The following is provided as general information deemed important when operating in a BRZ.

   a. The waters immediately around the structures and channels at the project present fixed and dynamic hazards to personnel & equipment performing work in close proximity to these areas.

   b. Cables and wires may span the channels both upstream and downstream of the powerhouses and spillway structures. The cables and wires may be both above and below the water level. Changing pool elevations cause a varying clearance between the water and cables or wires. The wires and cables are difficult to see in daylight and impossible to see during the hours of darkness.

   c. The structures have open, unprotected water inlets and outlets which are capable of ingesting, capsizing or swamping smaller vessels. These facilities have both remote and automatic operating capabilities.

   d. Water velocities at the surface and below, are constantly altered due to normal operation of the turbines and spillway gates. (These alterations may be done automatically or remotely).

   e. Protective relay actions can cause sudden water elevation variations resulting in a sudden increase or decrease in water velocities. These sudden elevation changes are sufficient in magnitude and duration to capsize a vessel, or pitch them into structures or wires when in close proximity. Personnel on-board vessels are at great risk of being cast overboard during sudden elevation changes due to load rejection events.

   f. Surface and submerged debris are an ever-present danger and are capable of fouling or breaking vessel propulsion or steering mechanisms.

   g. Boat entrance into the Forebay BRZ at night will not be allowed without meeting the requirements in this document and equipment being tagged out according to the 385-1-20 (Powerhouse Safer Clearance Procedure).

   h. Boat entrance into the Tailrace BRZ at night will not be allowed.

4. REQUIREMENTS.

a. Personnel and Vessel Safety Equipment.

(1) All BRZ entrances will be at the discretion of the Operator in Charge.

(2) All personnel must wear USCG approved personal flotation devices while in the BRZ.

(3) All vessels entering the BRZ will meet, but will not be limited to, Coast guard safety standards for day and night operations. Included are fire extinguishing capabilities, running and anchor lights, an audible warning device capable of being heard anywhere within the BRZ. Each vessel entering the BRZ will have either a current Coast Guard Certification or State inspection sticker on the boat demonstrating the equipment meets current safety standards.

(4) Depending on location, one boat with two motors or two boats (one being used as a rescue boat) will be required.

(5) A marine band radio capable of communication with the project Control Room on channel 14 must be available to the boat operator(s). Failure to maintain communication with the Control Room during the period the boat(s) are operating within the BRZ is cause for removal from the BRZ and future access denied.

(6) A rescue line shall be available in a throw bag or other approved device. The rescue line length shall be of sufficient length to reach personnel that have gone overboard. A minimum length of 50' is recommended. Line which is constructed of a buoyant material is also recommended.

(7) A spotlight that can be easily operated by the boat operator must be available.

(8) No vessel may enter the BRZ without proper coordination with the Operations Manager, or his/her representative. The applicant must submit a written request for access to the Operations Project Manager two weeks in advance of the anticipated work date(s). The request must include a schedule and written work plan. The work plan must include a description of the work to be performed, the locations of the work and any known project operating requirements or restrictions necessary. **Requests that require project support must be as far in advance as possible, but a minimum of 30 days prior to the anticipated need.**

(9) The applicant must submit a written JHA and activity hazard analysis (AHA) with the written request.

(10) A pre-work safety meeting will be held at the project prior to the anticipated work dates. The safety meeting must be attended by the Task/Work Leader or supervisor of the work crew.

(11) Immediately prior to entering the BRZ, entrants must contact the control room operator using marine band radio, channel 14, and request permission to enter the BRZ. The entrants must identify themselves and the BRZ to be entered. This will enable the control room operator the opportunity to relay any pertinent real time conditions about the BRZ prior to granting final approval. The BRZ entrants will contact the control room operator at the time they are leaving the BRZ.

(12) The project has two distinctive BRZs (Forebay & Tailrace) which are split up again between the Spillway and Powerhouse. They all present varying degrees of risk. Consequently, they have varying requirements.

b. BRZ Forebay Powerhouse. Operations in the Forebay BRZ in front of the powerhouse have the risk of vessels being pulled into structures, wires and cables. It is required to clear out the Main Unit Turbine and adjacent Main Unit Turbines during boating activity in the upstream BRZ that require approach closer than 400 feet to the Dam structure.

(1) The work vessel's second engine shall be of sufficient power that it can propel the boat and anticipated load upstream against current flows.

(2) If the nature of the work is outside of 400 feet from the Dam. BRZ entrants will have a second boat engine and standby safety boat for their activities while the Units are operating.

(3) Safety boats will be equipped with two engines, either of which is capable of propelling the boat and anticipated load upstream against current flows.

(4) While acting as the safety boat, occupants of the boat will have no other duties other than observing the primary boat inside the BRZ.

(5) The safety boat will meet all the other requirements listed in the section titled "Requirements."

c. BRZ Forebay Spillway. Operations in the Forebay BRZ at the Spillway have the additional risk of surface spill due to the Removable Spillway Weir (RSW). No BRZ entrances will be made in front of the Spillway until the RSW's spillway weir has been tagged out in accordance with 385-1-20. If the nature of the work is outside of 400 feet to the Spillway structure and the RSW is Tagged out, BRZ entrants will have a second boat engine and standby safety boat for their activities while spilling.

(1) The work vessel second engine shall be of sufficient power that it can propel the boat and anticipated load upstream against current flows.

(2) Safety boats will be equipped with two engines, either of which is capable of propelling the boat and anticipated load upstream against current flows.

(3) While acting as the safety boat, occupants of the boat will have no other duties other than observing the primary boat inside the BRZ.

(4) The safety boat will meet all the other requirements listed in the section titled "Requirements."

d. BRZ Forebay North of Unit 5 and South of Spillbay 2. When boat operations in the forebay require work North of Unit 5 and South of Spillbay 2 a combination of Powerhouse and Spillway requirements shall be used.

(1) No entrance into this area will be allowed without the RSW Tagged out.

e. BRZ Tail Race of Powerhouse. BRZ entrants will have a second boat engine and standby safety boat for their activities.

(1) The work vessel second engine shall be of sufficient power that it can propel the boat and anticipated load against current flows.

(2) Safety boats will be equipped with two engines, either of which is capable of propelling the boat and anticipated load against current flows.

(3) While acting as the safety boat, occupants of the boat will have no other duties other than observing the primary boat inside the BRZ.

(4) The safety boat will meet all the other requirements listed in the section titled "Requirements."

f. BRZ Spillway Tailrace. Operations in the Tailrace BRZ on the downstream side of the Spillway have the additional risk of being capsized from Navigational Lock drainage. Because of this increased risk, clear communication between the control room and boat operator is necessary. This shall also be addressed in the JHA. It is required to clear out the spillway during boating activity in the Tailrace BRZ that require approach closer than 200 feet to the Spillway structure. BRZ entrants will have a second boat engine and standby safety boat for their activities.

(1) The work vessel second engine shall be of sufficient power that it can propel the boat and anticipated load against current flows.

(2) Safety boats will be equipped with two engines, either of which is capable of propelling the boat and anticipated load against current flows.

(3) While acting as the safety boat, occupants of the boat will have no other duties other than observing the primary boat inside the BRZ.

(4) The safety boat will meet all the other requirements listed in the section titled "Requirements."

If the nature of the work is outside of 200 feet from the Spillway structure BRZ entrants will not be required to clear out the spillway. However, close communication is still necessary because of where the Navigational Lock drains. BRZ entrants will have a second boat engine and standby safety boat for their activities.

(1) The work vessel second engine shall be of sufficient power that it can propel the boat and anticipated load against current flows.

(2) Safety boats will be equipped with two engines, either of which is capable of propelling the boat and anticipated load against current flows.

(3) While acting as the safety boat, occupants of the boat will have no other duties other than observing the primary boat inside the BRZ.

(4) The safety boat will meet all the other requirements listed in the section titled "Requirements."

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