ENCLOSURE 1

T.W. Sullivan Powerhouse
Performance Report

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EXECUTIVE SUMMARY

Portland General Electric Company (PGE) was issued a New License for the Willamette Falls Project in December 2005. Among the conditions contained in the License was a stipulation that establishes a downstream juvenile salmonids passage protection goal of greater than or equal to 98% survival for downstream migrating salmonids as they pass through the T.W. Sullivan powerhouse. To help achieve the desired performance standard, PGE made several modifications to the powerhouse to improve forebay hydraulics and fish guidance. Following the construction phase, testing of Fish Guidance Efficiency (FGE) and route specific survival began in spring 2007, and occurred over a three year period. As outlined in the Settlement Agreement, information collected during these studies were used to establish an overall estimate of survival for out-migrating Chinook salmon and steelhead smolts entering the T.W. Sullivan forebay under typical powerhouse operations. This report provides: 1) an overview of studies conducted over the past three years in accordance with the Settlement Agreement to evaluate normal operating conditions; and 2) a comprehensive assessment using these data to estimate the overall survival rate for out-migrating salmonid smolts through the T.W. Sullivan powerhouse.

Passive integrated transponder (PIT) tags were used to evaluate the proportion of smolts passing through each passage route at the T.W. Sullivan powerhouse from 2007 to 2009. Tagged smolts were detected at one of two detection antennas located either on the newly constructed North Fish Bypass (NFB) or the existing Unit 13 Bypass. Each FGE test used a forebay ("treatment") release group to determine passage rates and simultaneous "calibration" releases to estimate detection efficiencies through each bypass. In total, 10,690 juvenile Chinook and 3,766 steelhead were tagged and released to evaluate FGE under normal operating conditions. These fish were released over multiple test groups (replicates) during the spring and fall migration periods. Data collected in 2007 were not combined with data collected in 2008 and 2009 for estimating powerhouse performance, because dramatic changes were made that improved the inner forebay hydraulics following the 2007 evaluation year.

For the purpose of evaluating project performance, an overall estimate of FGE was derived for each species. The overall estimate of FGE was computed as the weighted mean of the FGE estimates across replicate tests. This approach incorporates all data and requires no assumptions regarding constancy of detection probabilities and FGE across replicate tests. Based on simulations, the preferred weights were the inverse of the coefficient of variation (CV) of each FGE estimate, or inverse-CV weights. Using FGE data across 19 replicate tests for Chinook and 8 replicates for steelhead, the mean FGE estimates based on inverse-CV weights were 0.973 (95% CI: 0.938 – 1.008) for Chinook and 1.038 (95% CI: 1.005 – 1.071) for steelhead.

To evaluate survival of out-migrating smolts under normal operating conditions, the combined bypass system was divided into three sections based on the bypass configuration and feasibility of using particular testing methodologies. Direct survival of juvenile salmonids passing the modified bypass system was evaluated using a combination of various mark-recapture methodologies to assess passage related effects. Testing of all three bypass sections occurred in spring 2008.

The results of the individual evaluations indicate that direct survival through all the components of the modified fish bypass system was greater than 98% for both fish species. For the purpose of evaluating project performance, an overall estimate of survival for Unit 13 was required that combined survival through Reach-One (the upper reach) and Reach-Two (the Link Chute). The combined survival estimates for Unit 13 equaled 100.1% for Chinook and 98.4% for steelhead.

Overall survival or "Powerhouse Performance" was determined using fish passage rates through specific routes along with the corresponding survival rates experienced by smolts passing through each route (*i.e.*,

the two bypasses and turbines). Two approaches were used to estimate overall survival. The first approach assumed that survival rates through each bypass are the same, whereas in the second approach, estimates of passage and survival rates for the two bypasses are employed separately to estimate overall survival. For each approach, variance estimators were derived to quantify the precision of overall survival estimates.

Estimates of overall survival derived from either approach were greater than 99% and with levels of precision that met the performance standard. Overall survival rates derived using the first approach, which assumed that survival rates through each bypass are the same, were estimated to be 0.996 for Chinook (95% CI: ± 1.99%) and 0.994 for steelhead (95% CI: ± 1.01%). Using the second approach, which treated passage and survival rates separately for the two bypasses, overall survival rates were estimated to be 0.996 for Chinook (95% CI: ± 2.49%) and 0.998 for steelhead (95% CI: ± 1.12%). Furthermore, all estimates of overall survival were found to be robust to large reductions in assumed values of FGE or turbine survival rates. Injury rates were also extremely low; calculated to be less than 0.5% for both Chinook and steelhead.

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1.0 INTRODUCTION AND BACKGROUND

The Willamette Falls Hydroelectric Project is located at river mile 26.5 on the Willamette River in northwest Oregon (Figure 1). The T.W. Sullivan powerhouse is located adjacent to Willamette Falls, a naturally occurring, horseshoe shaped 40-ft-high basalt rock formation with a low concrete gravity dam along its entire crest. Willamette Falls marks the upstream boundary of the tidally influenced section of the lower Willamette River. The powerhouse contains 13 turbines including 12 vertical-axis Kaplan-type turbines and one Francis-type turbine (Unit 9). Each turbine has an intake from the forebay and discharges into the tailrace, which flows into the main river channel just below Willamette Falls. The powerhouse at peak generating capacity uses approximately 6,000 CFS to produce 17 megawatts.

On 8 December 2005, Portland General Electric Company (PGE) was issued an Order by the Federal Energy Regulatory Commission (FERC) approving the Settlement Agreement and issuing a New License for the Willamette Falls Project. Contained in the new FERC license is "Ordering Paragraph E" which makes the conditions submitted by the National Marine Fisheries Service (NMFS) under section 18 of the Federal Power Act a requirement of the license. Among the conditions contained in the License is a stipulation that establishes a downstream juvenile salmonids passage protection goal of greater than or equal to 98% survival for downstream migrating salmonids as they pass through the T.W. Sullivan powerhouse. Overall survival through the powerhouse (*i.e.*, "Powerhouse Performance") would be calculated using estimates of survival through each passage route and estimates of Fish Guidance Efficiency (FGE), a measure of the proportion of fish passing the powerhouse through non-turbine routes.

To help achieve the desired performance standard stipulated in the Settlement Agreement, PGE made several modifications to the powerhouse to improve forebay hydraulics and guidance of salmonid smolts away from T.W. Sullivan's turbines and safely past the Project. These included modifications to the inner forebay floor, intake rack and guidewall; construction of an additional bypass route (*i.e.*, the North Fish Bypass (NFB)); and construction of the "Link Chute" connecting the Unit 13 bypass to the NFB.

Following the construction phase, testing of FGE through the newly modified fish bypass system began in spring 2007, and occurred over a three year period. Direct injury and mortality studies of the bypass system were conducted in 2008. As outlined in the T.W. Sullivan Powerhouse Evaluation Study Plan (PGE 2007), information collected during these studies are to be used to establish an overall survival estimate for out-migrating Chinook salmon (*Oncorhynchus tshawytscha)* and steelhead (*O. mykiss*) smolts entering the T.W. Sullivan forebay under typical powerhouse operations. Typical or "normal" operating conditions are defined as having all turbine units on with both fish bypasses operating and flow through the NFB set at 400 cfs. This report provides: 1.) an overview of studies conducted over the past three years in accordance with the Settlement Agreement to evaluate normal operating conditions; and 2.) a comprehensive assessment using these data to estimate the overall survival rate for out-migrating salmonid smolts through the T.W. Sullivan powerhouse.

2.0 FISH GUIDANCE EFFICIENCY

2.1 Testing Overview

Passive integrated transponder (PIT) tags were used to evaluate the proportion of smolts passing through each passage route at the T.W. Sullivan powerhouse from 2007 to 2009. A PIT tag detection antenna was constructed specifically for the NFB and was installed in early 2007. The newly installed PIT tag antenna was similar to the existing antennas installed in the Unit 13 bypass downstream of the Eicher screen and just upstream of the evaluator catch tank (Figure 2).

As suggested by Skalski (2000), each FGE test used a forebay ("treatment") release group to determine passage rates and simultaneous "calibration" releases to estimate detection efficiencies through each bypass. Juvenile salmonids used for testing FGE were collected from the Unit 13 bypass evaluator. Hatchery Chinook and steelhead smolts were collected and tagged during the spring, but only hatchery Chinook were collected and tagged during the fall; juvenile steelhead do not migrate downstream in the Willamette River in the fall.

All fish selected for tagging were anesthetized, measured for length, and then injected with a standard 12 mm PIT tag using methods similar to those described in PGE (2007). One treatment and two calibration release sites were designated. Treatment fish were released into the forebay approximately 20 feet downstream of the main head gates through one of three release ports. Calibration fish were released immediately upstream of each PIT tag antenna using an induction device. Individual fish passage information was uploaded from each detection antenna to the PTAGIS website operated by the Pacific States Marine Fisheries Commission (PSMFC), where it was queried and downloaded for analysis.

Testing of FGE began immediately following the installation of the new PIT tag antenna in the NFB in spring 2007. However, early testing under normal operating conditions revealed lower than anticipated FGE. This was attributed to poor forebay hydraulics that occurred when the NFB was operating. Large hydraulic vortices, which were present along the inner forebay racks, intensified when flow increased beyond 250 cfs through the NFB. Hydraulic turbulence was especially apparent in the downstream portion of the forebay between the entrances of the NFB and Unit 13. Initial testing that varied the amount of flow passing through the NFB indicated that these hydraulic conditions negatively influenced FGE of downstream migrating smolts. To smooth the flow transition along the length the inner forebay racks and at the entrances of the fish passage facilities, partial barriers were installed intermittently along the inner trash racks, which diffused and noticeably reduced the hydraulic vortices. Subsequent testing in spring 2008 indicated improved FGE following the modification.

Because dramatic changes were made that improved the inner forehay hydraulics following the 2007 evaluation year, data collected in 2007 were not combined with data collected in 2008 and 2009 for estimating overall FGE and powerhouse performance. The complete interim report outlining results of the 2007 evaluation year is located in Interim Reports as Exhibit A.

In 2008 and spring 2009, the anticipated normal operating condition was evaluated. That is, all test fish were released while all turbine units were on with both bypasses were operating and flow through the NFB set at 400 cfs. The complete interim reports outlining results of the 2008 and 2009 evaluation years are located in Interim Reports as Exhibits B and C, respectively. The next section reports FGE estimates derived from the 2008 and 2009 evaluations.

2.2 Estimates of Fish Guidance Efficiency

During 2008 and 2009, 19 FGE tests were conducted under normal operating conditions for juvenile Chinook (Table 1), and 8 tests for juvenile steelhead (Table 2). A total of 10,690 Chinook and 3,766 steelhead were tagged and released to evaluate FGE under normal operating conditions. Approximately half were released as treatment fish whereas the remaining fish were split almost evenly between the NFB and Unit 13 calibration groups. The fork length of Chinook smolts used to evaluate FGE averaged 153 mm, whereas juvenile steelhead averaged 219 mm.

Across replicate tests, passage rates were much higher through the NFB than through Unit 13, and combined FGE was typically high, especially for steelhead. Chinook passage estimates through the NFB ranged from 0.68 to 1.05, while passage estimates through Unit 13 ranged from 0.00 to 0.13 (Table 1).

Note that true passage rates cannot exceed 1.0 (*i.e.*, 100%), though estimates may exceed 1.0 due to sampling variance. The combined estimates of Chinook passage rates through the two bypasses (*i.e.*, estimated FGE) ranged from 0.76 to 1.07 (Table 1). For steelhead, passage estimates were consistently high for the NFB (range: 0.92 to 1.07) and low for Unit 13 (range: 0.00 to 0.03), with combined FGE estimates ranging from 0.95 to 1.08 (Table 2). The formulas used to estimate these test-specific passage rates, FGEs, and their variances are provided in Appendix A. Appendix A also provides results of simulation analyses that confirm the accuracy of the estimators.

The use of multiple test groups was required to increase the statistical precision of overall FGE estimates (Skalski 2000). For each species, an overall estimate of FGE was computed as the weighted mean of the FGE estimates for each replicate test:

$$(1) \qquad \hat{\hat{g}} = \sum_{i=1}^{k} w_i \hat{g}_i \Big/ \sum_{i=1}^{k} w_i \; ,$$

where $\hat{\hat{g}}$ denotes the weighted mean estimate of FGE across k replicate tests, and w_i is the weight applied to the ith replicate estimate of FGE ($\hat{g}_i$). The variance of the weighted mean can be estimated as:

$$(2) \qquad \hat{\sigma}^2_{\hat{\hat{g}}} = \sum_{i=1}^{k} w_i \left(\hat{g}_i - \hat{\hat{g}}\right)^2 \Big/ (k-1) \sum_{i=1}^{k} w_i \; .$$

A standard practice is to assign weights equal to the inverse of the variance of each data point (*i.e.*, $w_i = 1/\hat{\sigma}^2_{\hat{g}_i}$), which in theory provides a minimum-variance estimator of the mean. However, the variance estimates for $\hat{g}_i$ are proportional to the estimates themselves, and such dependencies between data and weights may result in biased estimates. As detailed in Appendix A, the statistical properties of several alternative weighting schemes were examined using simulation analyses. Based on these analyses, the preferred weights were the inverse of the coefficient of variation (CV) of each FGE estimate (*i.e.*, $w_i = \hat{g}_i / \hat{\sigma}_{\hat{g}_i}$). We refer to these as inverse-CV weights.

The mean FGE estimates based on inverse-CV weights were 0.973 (95% CI: 0.938 – 1.008) for Chinook and 1.038 (95% CI: 1.005 – 1.071) for steelhead (Table 3). Also shown in Table 3 are estimates of the mean passage rates for each bypass, and their standard errors and covariance. These latter estimates, which are also based on inverse-CV weights computed using test-specific FGE estimates (see Appendix A), are needed to estimate overall project survival when survival rates are assumed to differ between bypasses (discussed below).

A key assumption of the FGE tests was that calibration fish and treatment fish had the same probability of detection. The fact that the 95% confidence interval of the mean FGE estimate for steelhead was greater than one (i.e., greater than 100% passage through the bypasses, which is not possible) strongly suggests that this assumption of equivalent detection rates may not be valid. To the extent that the true FGE for steelhead is very close to one, we would expect FGE estimates to exceed a value of one roughly 50% of the time due to sampling variance. However, steelhead FGE estimates exceeded one for seven of the eight replicate tests (Table 2), and across tests, the high mean estimate and its confidence interval imply that detection rates of calibration fish were likely lower on average than those of treatment fish. Calibration fish were released directly into the bypasses and immediately upstream of the detection antennas, whereas treatment fish entered the bypasses volitionally. Since fish orientation strongly influences the probability of detection by a PIT tag reader (Zydlewski *et al*. 2006), it is possible that differences in body orientation immediately after exiting the release pipe could result in lower detection rates among calibration fish (i.e., underestimates of p for treatment fish). This would in turn lead to overestimates of bypass passage rates (f) and FGE (g). We refer to this as "experimental bias," as apposed to "estimator bias," which was shown via simulations to be negligible (Appendix A). As discussed below in Section 4.3, the implications of potential experimental bias on estimates of overall survival were examined using sensitivity analyses.

2.3 Changes to the Methods Used in Previous Reports

The methods employed here to estimate FGE differ somewhat from those used in the 2008 evaluation year (Interim Reports, Exhibit B). Specifically, three basic changes were made to the statistical estimators of FGE. First, bias-corrected estimators were derived for test-specific estimates of passage rates and FGE (Appendix A). However, because detection probabilities were generally high, the bias-corrected estimates were very similar to previous estimates.

Second, a different variance formula was used for test-specific estimates of FGE (Appendix A). The previous variance formula was derived using a method that was unnecessarily complex, and terms were mistakenly dropped in the derivation that resulted in much larger variance estimates for FGE than warranted (Appendix A). After correcting this formula, it provides very similar estimates to the new, preferred estimator.

Last, the most important change concerns estimation of overall FGE (*i.e*., the approach used to combine replicate tests). In previous reports, efforts were made to pool data across replicate tests so that test-specific formulas could then be used to estimate overall FGE. However, this approach required that pooling only occur across tests with statistically similar detection probabilities, which resulted in the omission of numerous test results. Moreover, to provide valid inferences, the pooling approach also requires that FGE be essentially "fixed" over time, that is, all variation in FGE estimates is assumed to reflect only sampling variance. This latter assumption is quite restrictive.

Instead, overall FGE is now estimated using weighted means as noted above. This approach incorporates all data and requires no assumptions regarding constancy of detection probabilities and FGE across tests. The simulation analyses described in Appendix A indicated that means based on inverse-CV weights should provide accurate estimates of mean FGE and its variance for the Chinook and steelhead data sets examined here.

3.0 SURVIVAL AND CONDITION TESTING

3.1 Bypass Testing Overview

For the purpose of testing fish survival and condition under normal operating conditions, the combined bypass system at the T.W. Sullivan powerhouse was divided into three sections: 1) the new NFB section; 2) the Unit 13 Reach–One section extending from inner trash racks at the entrance of Unit 13 to immediately downstream of the fish evaluator; and 3) the Unit 13 Reach–Two section or "Link Chute" extending immediately downstream of the fish evaluator to the exit of the NFB outfall chute (Figure 3). Survival and condition testing at all three bypass sections occurred in spring 2008.

Direct survival and injury of juvenile salmonids passing through the NFB and Reach-Two (Link Chute) were assessed using the HI-Z Tag methodology; which compares the condition of live fish released upstream (treatment group) and downstream (control group) of a particular passage route to directly assess passage related effects (Heisey *et al*. 1992). Because the configuration of the upper portion of the Unit 13 bypass was not conducive for the use of HI-Z tags, a more traditional mark-recapture study was designed to evaluate fish condition and survival for Reach-One. The interim report for the survival and condition studies is located in Interim Reports as Exhibit D.

3.2 North Fish Bypass

One hundred and ninety-nine Chinook and 251 steelhead were tagged using HI-Z tags and released through the NFB while it was operating at 400 cfs. Chinook smolts released during this test averaged 153 mm and juvenile steelhead averaged 193 mm. In addition to the primary test flow of 400 cfs, a second test flow of 250 cfs was also evaluated using both species. This additional test was secondary to the primary objectives and was undertaken after the statistical goals of the primary test were met.

The results of the HI-Z tag evaluation indicated that the NFB is a benign passage route for juvenile Chinook and steelhead at 400 cfs flow. For both species, the direct survival estimates were in excess of 99% (Table 4). Malady rates, which included fish recaptured with physical injuries, descaling and/or neurological damage (*e.g.,* swimming erratically), were less than 0.5%. Similar results were found for smolts released under lower flow conditions, suggesting that flows as low as 250 cfs are not detrimental for fish passing through the NFB.

3.3 Unit 13 Bypass

3.3.1 Reach-One (upper bypass reach)

A mark-recapture study using fish without physical injuries or descaling was used to evaluate fish survival and condition following passage through the inner forebay and Reach-One, the upper section of the Unit 13 bypass. This approach was developed after the 2007 evaluation of Reach-One indicated a difficulty in discerning whether injuries (particularly descaling) observed on run-of-the-river smolts randomly collected in the bypass were passage related, or occurred prior to entering the powerhouse (Interim Reports, Exhibit A). The use of "known" fish, which were free of injury, allowed for a more accurate assessment of the type and severity of injuries that occurred during passage as well as the potential causal mechanisms.

Juvenile Chinook and steelhead free of injuries and obtained from a hatchery were marked with a fin-clip and released at the head of the trash racks leading into the inner forebay. A portion of these fish were then recollected downstream at the Unit 13 evaluator following passage through the inner forebay and Reach-One of the Unit 13 Bypass. The condition of recaptured fish was assessed using methods similar to those during studies conducted between 1991 and 1997 (PGE 1998), and described in (PGE 2007). A total of 629 hatchery reared Chinook salmon and 479 steelhead smolts were marked and released.

Estimated survival following passage through the inner forebay and upper portion of the Unit 13 Bypass (Reach-One) was in excess of 99% for both species (Table 4). These results were consistent with those reported in 2007 when run-of-the-river fish were randomly selected and held for 48 hours (Interim Reports, Exhibit A). However, the malady rates for fish released in 2008 were considerably lower than those reported in 2007.

Juvenile Chinook released in 2008 had a combined malady rate of 3%, and the malady rate for steelhead was less than 1.5%. These rates were dramatically lower than those estimated in 2007, which reported a combined malady rate of nearly 40% for Chinook and 42% for steelhead. This large difference in malady rates was attributed in part to releasing fish of known condition and removing maladies occurring upstream of the Project from the sample. Improved hydraulic conditions along the inner forebay and bypass entrances between study years may also explain the lower malady rates. Modification to the inner forebay in early 2008 reduced the large hydraulic vortices, which had formed along the inner intake screens and were thought to negatively affect passage efficiency and fish condition.

3.3.2 Reach-Two (Link Chute)

Similar to the NFB evaluation, juvenile Chinook and steelhead were used to evaluate survival and condition following passage through the Link Chute of the Unit 13 bypass (Reach-Two) using HI-Z tags. Smolts were released just upstream of the Link Chute, and then transitioned into the NFB with 400 cfs flow. In total, 199 juvenile Chinook averaging 151 mm in length, and 252 steelhead smolts averaging 192 mm were released. Also similar to the NFB evaluation, a second lower operating flow of 250 cfs passing through the NFB was evaluated for both species passing through the Link Chute.

Similar to smolts passing through the NFB, the survival estimates for juvenile Chinook and steelhead passing through the Link Chute were high (Table 4). For both species, survival estimates were greater than 98% under normal operating conditions. Malady rates were also low for both species (<1%). Of the few maladies observed that were associated with passing through the Link Chute, most appeared to be caused by mechanical forces caused by contact or abrasion on the floor or walls of the NFB as fish exited the Link Chute.

High survival rates and low malady rates were also found at lower flow conditions, suggesting that flows as low as 250 cfs are not detrimental for fish transitioning into the NFB from the Link Chute.

3.3.3 Combined Survival Estimates for Unit 13

For the purpose of evaluating project performance, an overall estimate of survival rate for Unit 13 is required that combines survival through Reach-One (the upper reach) and Reach-Two (the Link Chute). The combined survival rate for Unit 13 is estimated as:

$$\hat{s}_{\text{Unit 13}} = \hat{s}_{\text{Reach1}}\hat{s}_{\text{Link}},$$

with variance (Goodman 1960):

$$\hat{\sigma}^2_{\hat{s}_{\text{Unit 13}}} = \hat{s}^2_{\text{Reach1}}\hat{\sigma}^2_{\hat{s}_{\text{Link}}} + \hat{s}^2_{\text{Link}}\hat{\sigma}^2_{\hat{s}_{\text{Reach1}}} - \hat{\sigma}^2_{\hat{s}_{\text{Link}}}\hat{\sigma}^2_{\hat{s}_{\text{Reach1}}}.$$

The combined survival estimates for Unit 13 equaled 100.1% for Chinook and 98.4% for steelhead (Table 4).

3.4 Turbine Survival Estimate

An evaluation of survival through the turbines was not completed as a part of the post-license biological evaluation process. For calculating overall Powerhouse Survival Performance, PGE agreed to use a survival estimate for both Chinook and steelhead of 84.1% (PGE 2007), the value used in the FERC Final Environmental Assessment (FEA) for the Willamette Falls licensing. This weighted estimate was derived using survival probabilities generated during the 1997 evaluation of turbine passage survival using HI-Z tags (Normandeau and Skalski 1997). This study found that juvenile Chinook and steelhead had similar survival estimates following passage through the powerhouse, with estimates of 82.0% and 85.1%, respectively (Table 4). (The latter estimate for steelhead is based on the 1-h survival estimate, which was lower than the 48-h estimate.)

4.0 POWERHOUSE PERFORMANCE ESTIMATION

Overall survival or "Powerhouse Performance" is determined by fish passage rates through alternative routes and the corresponding survival rates experienced by juveniles in each route. Two approaches were used to estimate overall survival. The first approach assumed that survival rates through the two bypasses (*i.e.*, NFB and Unit 13) are the same, such that survival-rate estimates can be combined to provide a single*, more precise*, estimate of bypass survival. This approach is consistent with the emphasis that has been placed on estimating FGE, the *combined* measure of passage rate through the two bypasses. In the second approach, estimates of passage and survival rates for the two bypasses are employed separately to estimate overall survival.

For each approach, variance estimators were derived to quantify the precision of overall survival estimates (Appendix B). This is important because in addition to achieving the overall survival objective of greater than or equal to 98% survival, the precision of the survival estimate is a key determinant of whether the desired performance standard has been achieved. Previous goals of obtaining specified precisions (*i.e*., 95% confidence intervals of ± 2.5%) for FGE and route-specific survival estimates were based on the assumption that these precisions would provide an acceptable precision (though unspecified) for overall survival estimates. A more robust assessment of precision can now be obtained using the variance estimators for overall survival estimates.

In the calculations below, a survival rate of 84.1% was applied to either Chinook or steelhead juveniles that were assumed to pass through the turbines, consistent with the PGE agreement (PGE 2007). To estimate the precision of overall survival, the variance of the turbine survival-rate estimate is also required. The variance used for both Chinook and steelhead was $(0.0286)^2$, which corresponds to the larger standard error (SE) of the two turbine survival estimates reported in Table 4.

4.1 Approach 1: Combined Bypasses

In this approach, fish are assumed to travel either through the bypasses (with passage probability = g and survival = s_1) or through the turbines (with passage probability = 1 - g and survival = s_2). For this combined-bypasses scenario, the estimate of overall survival (S) is given by (Appendix B):

(3) $$\hat{S} = \hat{g}\hat{s}_1 + (1-\hat{g})\hat{s}_2 \ ,$$

with variance estimator:

(4) $$v[\hat{S}] = \left(\hat{g}^2 - v[\hat{g}]\right)v[\hat{s}_1] + \left((1-\hat{g})^2 - v[\hat{g}]\right)v[\hat{s}_2] + (\hat{s}_1 - \hat{s}_2)^2 v[\hat{g}] \ ,$$

where v denotes an estimated variance (*e.g*., $v[\hat{S}] = \hat{\sigma}^2_{\hat{S}}$). The estimate of g is the weighted mean FGE described above using inverse-CV weights (Table 3). As noted above, the estimate of s_2 (turbine survival rate) was set to 0.841 for both Chinook and steelhead.

The key assumption of this approach lies in the estimation of bypass survival (s_1). It is clear that survival estimates for NFB and Unit 13 are very similar within and between species, and close to one in all cases (Table 4). Assuming that survival rates are essentially the same between bypasses, a more precise estimate of combined-bypass survival can be obtained by computing their mean based on inverse-variance weights:

$$\hat{s}_1 = \frac{\dfrac{\hat{s}_{\text{NFB}}}{\hat{\sigma}^2_{\hat{s}_{\text{NFB}}}} + \dfrac{\hat{s}_{\text{Unit 13}}}{\hat{\sigma}^2_{\hat{s}_{\text{Unit 13}}}}}{\dfrac{1}{\hat{\sigma}^2_{\hat{s}_{\text{NFB}}}} + \dfrac{1}{\hat{\sigma}^2_{\hat{s}_{\text{Unit 13}}}}}$$

with variance

$$\hat{\sigma}^2_{\hat{s}_1} = \frac{1}{\dfrac{1}{\hat{\sigma}^2_{\hat{s}_{\text{NFB}}}} + \dfrac{1}{\hat{\sigma}^2_{\hat{s}_{\text{Unit 13}}}}}.$$

The estimates of combined bypass survival (s_1) for each species are shown in Table 5, together with estimates for g and s_2. These estimates and their variances were used in equations (3) and (4) to estimate overall survival (S). Note that to estimate S, the value of s_1 for Chinook was set equal to 1.0 because the actual estimate was slightly greater than 1.0 (which is not possible). In addition, the estimate of g (FGE) for steelhead was also greater than one, implying no fish would ever travel through the turbines. To provide a more probable (and conservative) estimate of overall survival for steelhead, g was set to 0.99.

Given these adjustments, overall survival rates were estimated to be 0.996 for Chinook (95% CI: 0.976-1.000) and 0.994 for steelhead (95% CI: 0.984-1.000) (Table 5). The precision levels for the 95% confidence intervals were ± 1.99% for Chinook and ± 1.01% for steelhead.

4.2 Approach 2: Separate Bypasses

In this approach, the two bypasses (NFB and Unit 13) are treated separately with respective passage rates (f_1 and f_2) and survival rates (s_1 and s_2). Fish travel through the turbines with passage probability = 1 - f_1 - f_2 and survival = s_3. For this separate-bypasses scenario, total project survival (S) is given by (Appendix B):

(5) $$\hat{S} = \hat{f}_1\hat{s}_1 + \hat{f}_2\hat{s}_2 + (1 - \hat{f}_1 - \hat{f}_2)\hat{s}_3 \ ,$$

with variance estimator:

(6)

$$\begin{aligned} v[\hat{S}] = {} & \hat{f}_1^2 v[\hat{s}_1] + \hat{f}_2^2 v[\hat{s}_2] + (1 - \hat{f}_1 - \hat{f}_2)^2 v[\hat{s}_3] + \left((\hat{s}_1 - \hat{s}_3)^2 - v[\hat{s}_1] - v[\hat{s}_3]\right)v[\hat{f}_1] \\ & + \left((\hat{s}_2 - \hat{s}_3)^2 - v[\hat{s}_2] - v[\hat{s}_3]\right)v[\hat{f}_2] + 2(\hat{s}_3^2 + \hat{s}_1\hat{s}_2 - \hat{s}_1\hat{s}_3 - \hat{s}_2\hat{s}_3 - v[\hat{s}_3])v[\hat{f}_1, \hat{f}_2] \end{aligned},$$

where $v[f_1, f_2]$ denotes the covariance estimate for f_1 and f_2.

The required estimates for passage rates (f_1 , f_2, and $v[f_1 , f_2]$) correspond to the weighted estimates shown in Table 3, while estimates for survival rates (s_1 , s_2, and s_3) correspond to values in Table 4. For clarity, these estimates are also presented in Table 5. These estimates and their variances were used in equations (5) and (6) to estimate overall survival (S) for the separate-bypass approach (Table 5). However, to estimate S, the values of s_1 and s_2 for Chinook were set equal to 1.0 because both bypass-survival estimates were slightly greater than 1.0. The passage-rate estimate (f_1) for steelhead through the NFB was also greater than one. This value was set to 0.976 so that the total bypass passage rate ($f_1 + f_2$) for steelhead equaled 0.99 (consistent with the combined-bypass approach above in Section 4.1).

Given these adjustments, overall survival rates were estimated to be 0.996 for Chinook (95% CI: 0.971-1.000) and 0.998 for steelhead (95% CI: 0.987-1.000) (Table 5). The precision levels for the 95% confidence intervals were ± 2.49% for Chinook and ± 1.12% for steelhead.

4.3 Summary and Sensitivity Analysis

The two approaches above yielded similar estimates of overall survival for each species. To reiterate, the two approaches used different estimates of bypass survival rate. In the first "combined-bypasses" approach, survival rates were assumed to be the same for both bypasses, which allowed for the estimation of a more precise estimate of combined bypass survival. In contrast, in the "separate-bypasses" approach, different survival rates were used for each bypass. However, for Chinook, the two approaches resulted in the *same* point estimate of overall survival (S = 0.996; Table 5) because in both cases all bypass-survival estimates were set equal to 1.0 (*i.e.,* the actual estimates were slightly greater than one). Thus, the only difference for Chinook was that the combined-bypasses approach yielded a slightly lower standard error for S (SE = 0.0102) than did the separate-bypasses approach (SE = 0.0127). For steelhead, the separate-bypasses approach provided a slightly higher (but less precise) estimate of overall survival (S = 0.998 vs. S = 0.994 for combined-bypasses) (Table 5). The estimate of S was higher for the separate-bypasses approach because the survival-rate estimate for the NFB was greater than for Unit 13, and most fish passed through the former. Overall, however, there was little difference in the results for either species depending on the assumptions used to incorporate bypass survival estimates.

For steelhead, a more important assumption surrounds the value used for FGE (g). Because the estimated mean FGE was greater than one, it was arbitrarily set to 0.99 in the combined-bypasses approach (thereby assuming that 1% of fish travel through the turbines). Similarly, in the separate-bypasses approach, the passage-rate estimate for the NFB (f_1 = 1.025) was set to 0.976 so that combined passage rate (FGE) through the bypasses again equaled 0.99 (*i.e.*, NFB + Unit 13 = $f_1 + f_2 = g$). In either case, if FGE is assumed to be greater than 0.99, then the overall survival estimate for steelhead will increase, and vice-versa. On the other hand, the fact that mean FGE for steelhead was greater than one is a strong indication that there may have been "experimental bias" associated with FGE estimates (i.e., calibration releases underestimated detection rates of treatment fish). The implications of this potential bias on overall survival estimates for Chinook and steelhead are discussed below.

The "robustness" of the overall survival estimates can be examined using alternative assumptions regarding the values of FGE, and for comparison, alternative values of turbine survival rate. These sensitivity analyses examine the lowest possible values of FGE or turbine survival rate that would still result in overall survival estimates of 0.98 (98%). For example, using parameter values for the combined-bypasses approach, FGE (g) would have to be less than 0.87 for Chinook and 0.90 for steelhead in order for overall survival (S) to be less than 0.98 (98%). Such values of FGE are far below the estimated 95% confidence intervals for mean FGE. Alternatively, turbine survival (s_2) would have to be less than 0.25 (25%) for Chinook in order for S < 0.98 (98%). In the case steelhead with FGE (g) = 0.99, S is still greater than 0.98 even when turbine survival (s_2) equals 0.0 (S = 0.986 in this case). Very similar results were found for the separate-bypasses approach. In other words, given the high estimates of bypass survival rates for both Chinook and steelhead, the estimates of overall survival (S) for both species are very robust to large reductions in assumed values of FGE (g) and turbine survival rates.

To examine the influence of potential experimental bias on estimates of overall survival, sensitivity analyses were conducted as follows. It was assumed that some proportion of a given calibration release group was not detected due to physical processes unique to calibration fish, whereas those fish would have been detected had they entered a given bypass volitionally (i.e., had they been part of the treatment release). A range of hypothetical proportions was specified from 0% (no bias) to 50%. For example, a value of 50% implied that half of the *undetected* calibration fish – for a given FGE test and bypass – should have been detected in order to provide an unbiased estimate of detection rate for the treatment release group. Thus, if the calibration detection rate (p) was estimated to be 70%, it was increased to 85% under the maximum assumed bias of 50% of undetected calibration fish. Each assumed bias proportion was applied to both bypasses (Unit 13 and the NFB) and all replicate FGE tests for a given species, providing corresponding estimates of passage rate, FGE, and overall survival. In this case, mean estimates of passage rate or FGE were non-weighted estimates (weighting required test-specific variance estimates, which have little meaning in the context of these hypothetical sensitivity analyses), and overall survival was estimated using the "separate bypasses" approach (results were essentially the same for the "combined bypasses" approach).

The results of these sensitivity analyses are shown in Figure 4 for Chinook and Figure 5 for steelhead. For Chinook juveniles, as the assumed level of bias increased, the implied average detection rates (p) of treatment fish increased, whereas average FGE and overall survival declined (Figure 5). The baseline condition (no bias) is represented at 0% on the x-axis, for which calibration detection rates averaged 0.81 (NFB) and 0.84 (Unit 13), mean FGE was 0.956 (unweighted mean), and the corresponding overall survival estimate equaled 0.993 (Figure 5). In contrast, assuming that 50% of *undetected* calibration fish *should have been detected,* to truly represent treatment fish (a high level of assumed bias), implies that mean detection rates of treatment fish were actually 0.91 (NFB) and 0.92 (Unit 13), mean FGE was 0.858, and overall survival would be estimated at 0.977 (Figure 5). Thus, a high level of assumed bias in calibration detection rates is required in order for the overall survival estimate for Chinook juveniles to drop slightly below 98%. For steelhead, a high level of assumed bias (50%) resulted in implied estimates of FGE = 0.969 and overall survival = 0.995 (Figure 5). In fact, even when detection rates for treatment fish are assumed to be 100% (i.e., all undetected calibration fish were biased non-detections), FGE = 0.909 and overall survival = 0.985. Thus, the overall survival of steelhead is estimated to be greater than 98% even under the most extreme assumption of possible detection bias.

Finally, it is worth noting that the primary source of variation in overall survival-rate estimates was due to uncertainty in bypass survival estimates, rather than from estimates of FGE or turbine survival. In other words, the estimates $v[\hat{S}]$ were largely determined by the estimates $v[\hat{s}_1]$ in equations (4) and (6). This makes intuitive sense because the vast majority of fish travel through the bypasses (especially the NFB), so uncertainty in overall survival depends primarily on the uncertainty in bypass survival.

Overall injury rates (*i.e.,* the proportion of fish sustaining non-lethal injuries) can be determined in a manner similar to that above for survival rates. Estimates of injury rates are low because few injuries were observed among fish recovered in the bypass-survival tests (Interim Reports, Exhibit D). Because over 90% of bypassed Chinook and steelhead pass through the NFB (Table 3), the overall injury rates are characterized largely by these fish, and therefore heavily weighted toward zero. To demonstrate this, overall powerhouse injury was estimated using equation (5) by replacing estimates of individual bypass survival $(\hat{s}_i)$ with values of injury derived for each bypass route (*i.e.*, NFB and Unit 13; Interim Reports,

Exhibit D). Using the bypass guidance rates ($\hat{f}_i$) used to derive overall survival, and the injury rates reported for each species passing through the turbines (Normandeau and Skalski 1997), an overall injury rate was calculated to be less than 0.5% for both Chinook and steelhead; rates which satisfies the smolt injury performance standard of 2% or less.

In conclusion, based on comprehensive FGE and survival experiments, overall survival ("Powerhouse Performance") was estimated to exceed 99% for both Chinook and steelhead smolts. The estimates of overall survival are quite precise, with 95% confidence intervals of roughly ± 2.5% for Chinook and ± 1.1% for steelhead. Furthermore, these estimates are robust to large reductions in assumed values of FGE and turbine survival rates.

5.0 Other T.W. Sullivan Powerhouse Performance Testing

While this report focused on evaluating the overall survival rate for out-migrating salmonid smolts through the T.W. Sullivan Powerhouse, other post-construction evaluation objectives, which were outlined in the T.W. Sullivan Powerhouse Evaluation Study Plan (PGE 2007) and developed in accordance with License Article B.3.(b), are addressed below.

In accordance with Objective 3, fall 2009 testing of unit shutdowns on fish guidance through the powerhouse indicates there is no measurable impact on fish guidance performance (Exhibit E). Two scenarios were tested during conditions specified in the T.W. Sullivan Powerhouse Operations Plan (PGE 2008) for when one or two turbines are shutdown as a result of low river flow. A single-unit shutdown scenario was tested with all turbine units operating except for Unit 11. A two-unit shutdown (Units 4 and 9) was also tested. For both scenarios, estimated FGE was calculated to be 100% (± 6%).

As stipulated in Objective 4 of the T.W. Sullivan Powerhouse Evaluation Study Plan, mortality and injury of salmonid fry or juvenile lamprey passing the powerhouse and NFB were not assessed because of the lack of acceptable field research technology applicable to conditions existing at the Project.

Additionally, in accordance with Objective 5 of the Study Plan, an evaluation of the potential injury and mortality caused by the 2-inch bar spacing of the inner trashracks was not warranted due to high guidance efficiency of smolts to the fish bypass systems and associated high passage performance.

To address Objective 6, operation changes were evaluated for Unit 13 to alleviate any possible stranding issues. Current operation provides approximately 40 cfs of water to continue to pass through the Unit 13 bypass in the event that the Unit 13 turbine is shut down over a short time period. A continual supply of water helps maintained dissolved oxygen concentrations and ambient water temperatures along the upper portion of the bypass. Additionally, the Unit 13 bypass plunge pool has the option of a tailrace pump that allows continuous water supply in the event this area should be isolated. There has been no evidence of stranding issues at the NFB during shutdown as a result of the steep incline of the bypass chute, high velocities during controlled NFB closure, and relatively brief window of opportunity for stranding to occur.

While not a specific Objective of the Study Plan, given the modifications made to improve hydraulics and fish guidance through the T.W. Sullivan forebay, along with the high bypass performance results for juvenile Chinook and steelhead, there is no evidence suggesting that the qualitative performance goals of "safe, timely, and effective", provided in License Article B.1(e) (Table 2), are not being met for adult salmonids (*e.g.,* fallback and steelhead kelts), or for adult lamprey, passing through the powerhouse.

6.0 REFERENCES

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TABLES

Table 1.

Data for 19 replicate tests of FGE for juvenile Chinook conducted during the 2008 and 2009 evaluation years. For NFB (or Unit 13) calibration groups, R_1 (or R_2) denotes the number of fish released, c_1 (or c_2) is the number of fish detected, and p_1 (or p_2) is the estimated detection probability for the bypass. For treatment groups, R_T is the number of fish released and t_1 and t_2 are the number of fish detected in the NFB and Unit 13 bypasses, respectively. Also shown are the estimates of passage rate for NFB (f_1) and Unit 13 (f_2), and the combined FGE estimate (g) and standard error (SE(g)). The estimators used for f_1, f_2, g, and SE(g) are the bias-corrected versions detailed in Appendix A.

		NFB Calibration			Unit 13 Calibration			Treatment Group			Passage Estimates			
Test	Date	R_1	c_1	p_1	R_2	c_2	p_2	R_T	t_1	t_2	f_1	f_2	g	SE(g)
1	3/26/2008	119	83	0.70	60	41	0.68	279	173	21	0.89	0.11	1.00	0.067
2	3/27/2008	157	117	0.75	60	44	0.73	172	114	7	0.89	0.06	0.94	0.062
3	4/2/2008	101	74	0.73	60	46	0.77	60	34	3	0.77	0.06	0.84	0.097
4	4/3/2008	60	44	0.73	60	52	0.87	122	88	4	0.98	0.04	1.02	0.091
5	4/4/2008	80	60	0.75	60	57	0.95	83	56	5	0.9	0.06	0.96	0.085
6	4/9/2008	60	49	0.82	59	55	0.93	119	71	9	0.73	0.08	0.81	0.068
7	4/10/2008	53	42	0.79	57	51	0.89	79	55	4	0.87	0.06	0.93	0.086
8	4/11/2008	49	41	0.84	56	53	0.95	166	116	14	0.83	0.09	0.92	0.064
9	4/17/2008	99	85	0.86	96	80	0.83	221	166	24	0.87	0.13	1.00	0.045
10	4/23/2008	60	56	0.93	66	62	0.94	128	81	10	0.68	0.08	0.76	0.049
11	11/6/2008	194	167	0.86	196	178	0.91	435	392	0	1.05	0.00	1.05	0.034
12	11/7/2008	315	264	0.84	336	301	0.90	607	516	4	1.01	0.01	1.02	0.030
13	11/13/2008	99	81	0.82	99	28	0.28	196	161	0	1.00	0.00	1.00	0.058
14	3/20/2009	277	232	0.84	248	226	0.91	432	341	18	0.94	0.05	0.99	0.033
15	3/27/2009	60	45	0.75	60	54	0.90	244	162	22	0.88	0.10	0.98	0.074
16	4/3/2009	179	156	0.87	179	168	0.94	625	449	57	0.82	0.10	0.92	0.030
17	4/9/2009	238	192	0.81	237	222	0.94	542	405	33	0.93	0.06	0.99	0.036
18	4/10/2009	236	198	0.84	241	196	0.81	498	415	30	0.99	0.07	1.07	0.033
19	4/17/2009	239	214	0.90	239	219	0.92	538	451	21	0.94	0.04	0.98	0.026
Total		2675			2469			5546						

Table 2.

Data for eight replicate tests of FGE for juvenile steelhead conducted during the 2008 and 2009 evaluation years. For NFB (or Unit 13) calibration groups, R_1 (or R_2) denotes the number of fish released, c_1 (or c_2) is the number of fish detected, and p_1 (or p_2) is the estimated detection probability for the bypass. For treatment groups, R_T is the number of fish released and t_1 and t_2 are the number of fish detected in the NFB and Unit 13 bypasses, respectively. Also shown are the estimates of passage rate for NFB (f_1) and Unit 13 (f_2), and the combined FGE estimate (g) and standard error (SE(g)). The estimators used for f_1, f_2, g, and SE(g) are the bias-corrected versions detailed in Appendix A.

		NFB Calibration			Unit 13 Calibration			Treatment Group			Passage Estimates			
Test	Date	R_1	c_1	p_1	R_2	c_2	p_2	R_T	t_1	t_2	f_1	f_2	g	SE(g)
1	4/24/2008	104	88	0.85	103	98	0.95	196	177	2	1.07	0.01	1.08	0.050
2	4/30/2008	114	100	0.88	119	110	0.92	173	155	1	1.02	0.01	1.03	0.044
3	5/1/2008	117	103	0.88	118	114	0.97	152	139	2	1.04	0.01	1.05	0.042
4	5/9/2008	146	129	0.88	147	135	0.92	234	212	5	1.02	0.02	1.05	0.036
5	5/16/2008	157	120	0.76	179	166	0.93	283	229	5	1.06	0.02	1.08	0.055
6	5/6/2009	150	139	0.93	20	18	0.90	190	162	5	0.92	0.03	0.95	0.033
7	5/15/2009	251	224	0.89	50	45	0.90	298	276	2	1.04	0.01	1.04	0.028
8	5/22/2009	167	153	0.92	32	26	0.81	266	255	1	1.05	0.00	1.05	0.027
Total		1206			768			1792						

Table 3.

Weighted means for FGE ($\bar{g}$) and passage rates through NFB ($\bar{f}_1$) and Unit 13 ($\bar{f}_2$). Also shown is the estimated covariance of $\bar{f}_1$ and $\bar{f}_2$. SE= standard error. Test-specific estimates are shown in Table 1 for Chinook and Table 2 for steelhead.

	Chinook (k = 19)		Steelhead (k = 8)	
	Estimate	SE	Estimate	SE
$\bar{g}$ (FGE)	0.973	0.0167	1.038	0.0140
$\bar{f}_1$(NFB)	0.914	0.0214	1.025	0.0160
$\bar{f}_2$ (Unit 13)	0.059	0.0087	0.014	0.0032
Cov($\bar{f}_1$, $\bar{f}_2$)	-1.27E-04		-3.54E-05	

Table 4.

Survival-rate estimates derived from release experiments. (SE = standard error; LCI = lower 95% confidence interval; UCI = upper 95% confidence interval.)

	Chinook				Steelhead			
	Estimate	SE	LCI	UCI	Estimate	SE	LCI	UCI
NFB[a]	1.010	0.0136	0.983	1.036	1.000	0.0054	0.989	1.010
Unit 13 reach 1[a]	0.996	0.0041	0.988	1.004	1.000	0	1	1
Unit 13 link chute[a]	1.005	0.0144	0.976	1.033	0.984	0.0095	0.965	1.002
Combined Unit 13	1.001	0.0149	0.971	1.030	0.984	0.0095	0.965	1.002
Turbine survival[b]	0.820	0.0286	0.764	0.876	0.851	0.0283	0.796	0.906

[a] Estimates provided in Normandeau (2008); Interim Report (Exhibit D)

[b] Estimates provided in Normandeau (1997).

Table 5.

Overall estimates of survival (S) based on two approaches that assume that survival rates through the two bypasses (NFB and Unit 13) are either the same (combined bypasses) or different (separate bypasses).

		Chinook		Steelhead	
Approach	Variable	Estimate	SE	Estimate	SE
Combined Bypasses	FGE (g)	0.973	0.0167	1.038[b]	0.0140
	Bypass survival (s1)	1.006[a]	0.0100	0.996	0.0047
	Turbine survival (s2)	0.841	0.0286	0.841	0.0286
	Overall survival (S)	**0.996**	**0.0102**	**0.994**	**0.0051**
Separate Bypasses	NFB passage (f1)	0.914	0.0214	1.025[c]	0.0160
	Unit 13 passage (f2)	0.059	0.0087	0.014	0.0032
	Cov(f1,f2)	-1.27E-04		-3.54E-05	
	NFB survival (s1)	1.010[a]	0.0136	1.000	0.0054
	Unit 13 survival (s2)	1.001[a]	0.0149	0.984	0.0095
	Turbine survival (s3)	0.841	0.0286	0.841	0.0286
	Overall survival (S)	**0.996**	**0.0127**	**0.998**	**0.0057**

[a] Estimate was set equal to 1.0 because the actual estimate was slightly greater than 1.0 (which is not possible).

[b] Estimate was set to 0.99, which assumes that some fish travel through the turbines (i.e., g -1 = 0.01 or 1% via turbines).

[c] Estimate was set to 0.976 so that the total bypass passage rate ($f_1 + f_2$) for steelhead equaled 0.99 (consistent with the combined-bypasses approach).

FIGURES

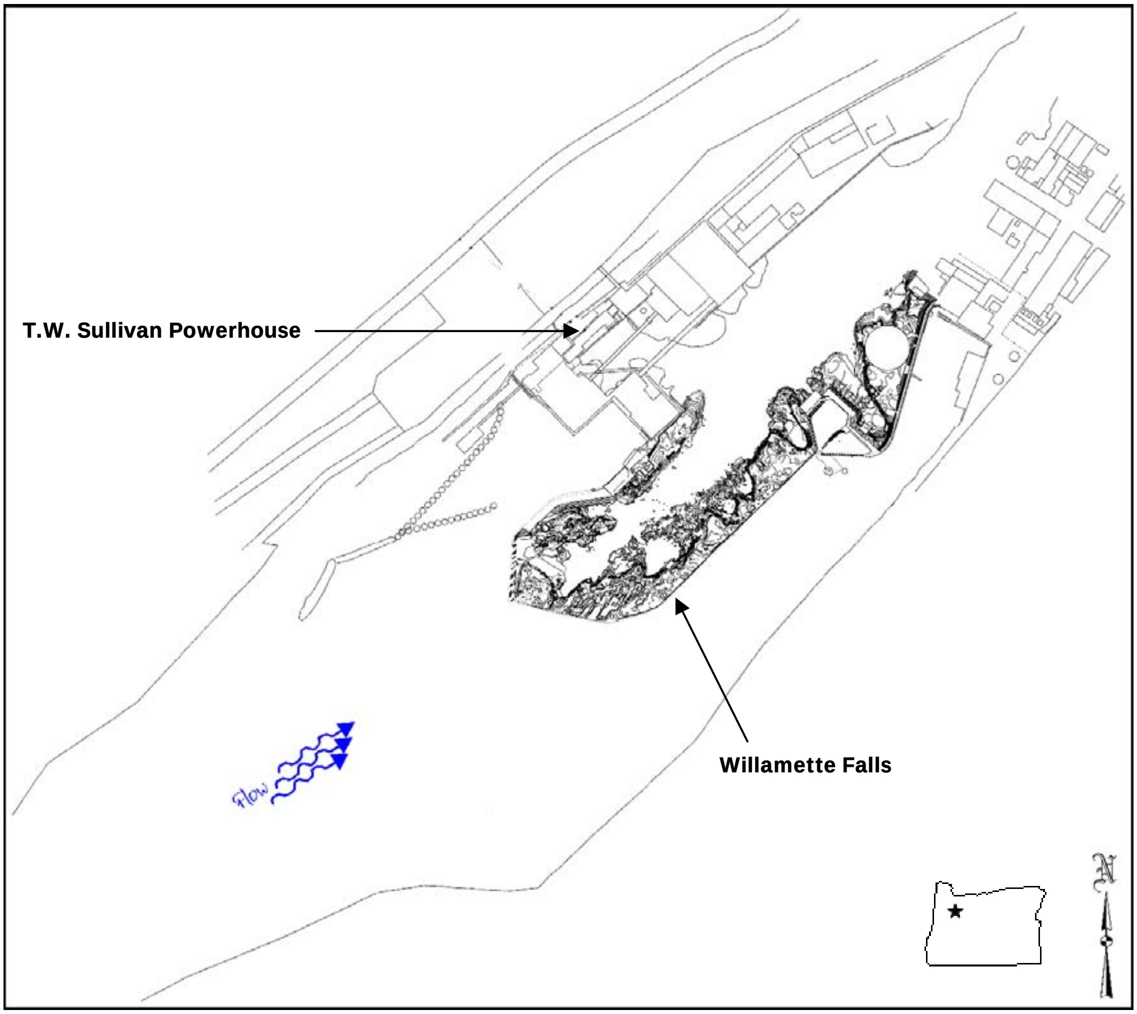

Figure 1.

Generalized layout of the Willamette Falls Project.

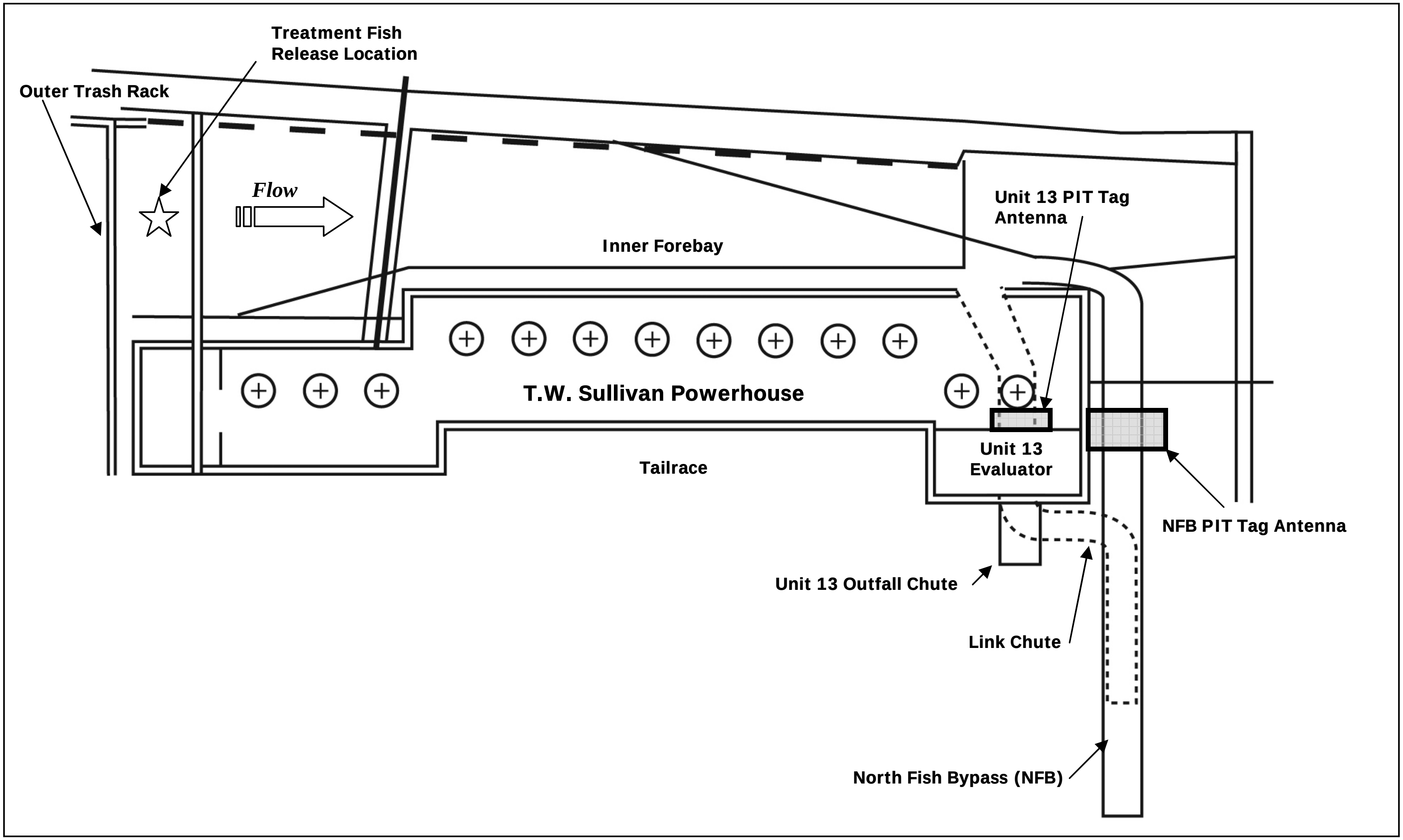

Figure 2.

T.W. Sullivan forebay and fish bypass facilities.

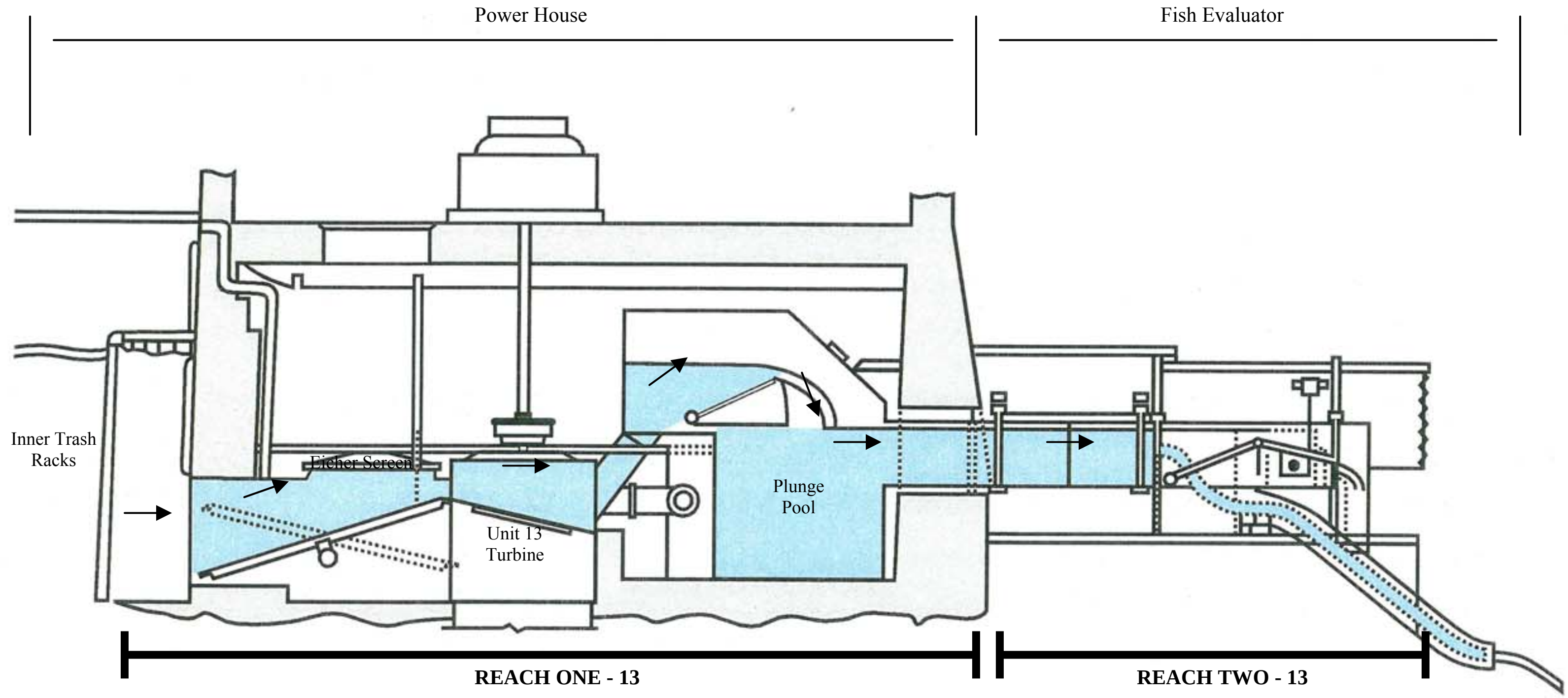

Figure 3.

Cross sectional diagram of the T.W. Sullivan Unit 13 Fish Bypass showing the upper area designated as Reach-One and the lower area designated as Reach-Two. (The Link Chute is also apart of Reach-Two, but is not illustrated here). Arrows indicate fish passage route.

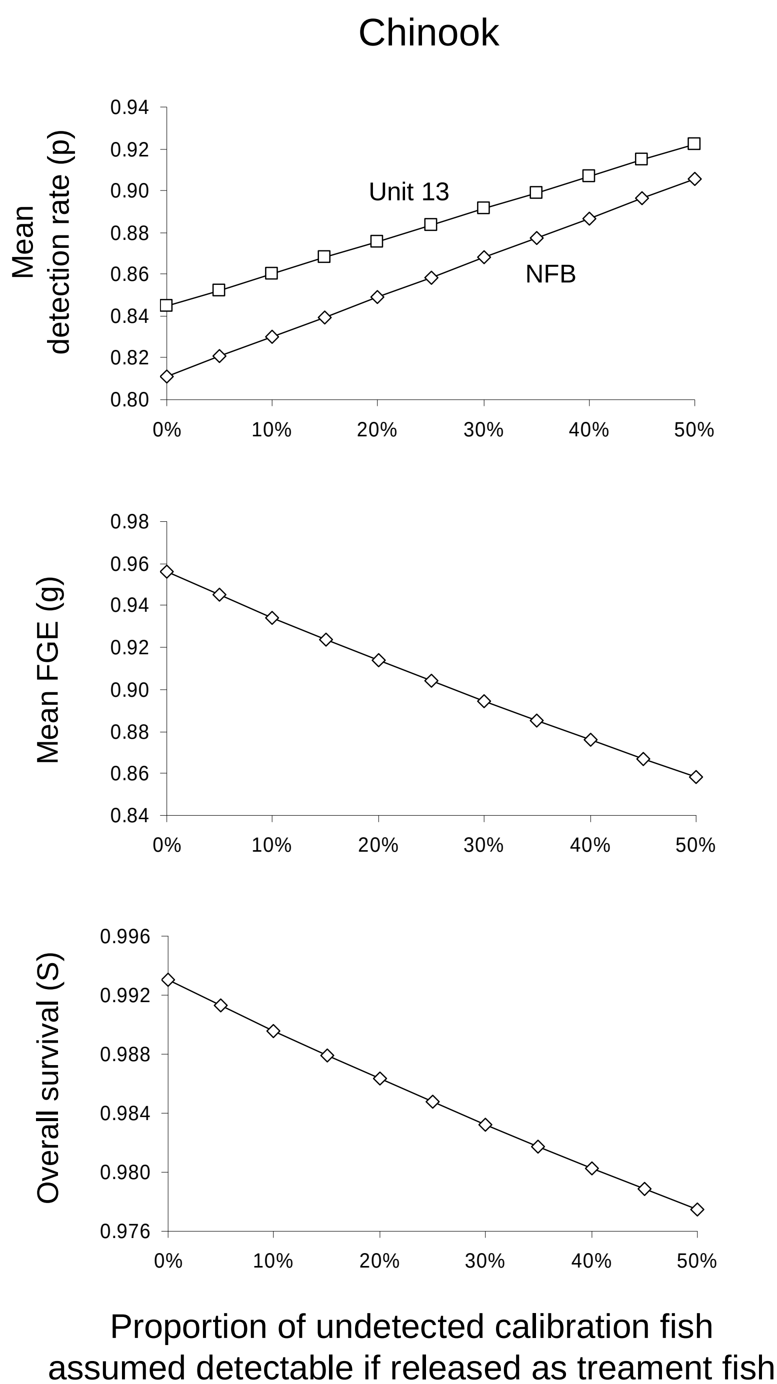

Figure 4.

Effects of hypothetical bias in detection rates (i.e., the proportion of undetected calibration fish assumed to be detectable as treatment fish; 0% = no bias) on mean detection rates (top panel), mean FGE (middle panel), and overall survival (bottom panel) across the 19 replicate FGE tests for Chinook juveniles.

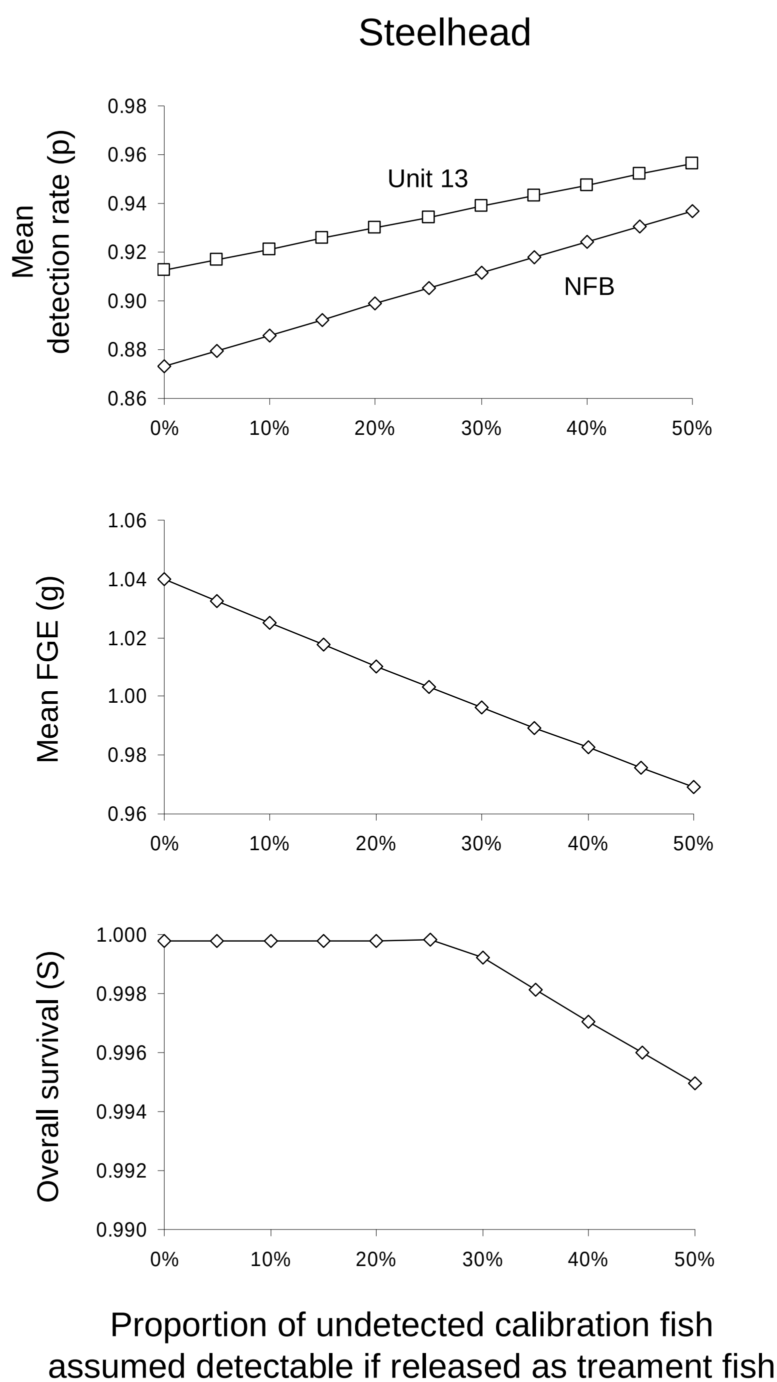

Figure 5.

Effects of hypothetical bias in detection rates (i.e., the proportion of undetected calibration fish assumed to be detectable as treatment fish; 0% = no bias) on mean detection rates (top panel), mean FGE (middle panel), and overall survival (bottom panel) across the eight replicate FGE tests for Steelhead juveniles.

Appendix A

Derivation and Evaluation of Statistical Estimators for Fish Guidance Efficiency

Derivation and Evaluation of Statistical Estimators for Fish Guidance Efficiency

Summary

The following sections provide analytical formulas for estimates of the proportion of fish using bypasses (passage rates) as derived from experimental releases of PIT-tagged Chinook or steelhead juveniles. Total passage rate via bypasses is termed "Fish Guidance Efficiency" or FGE, which is the sum of passage rates through the North Fish Bypass (NFB) and Unit 13 Bypass. Based on the derivations below and supporting simulation analyses, the preferred estimates of passage rate (denoted *f*) and its variance for a given bypass correspond to equations (A12) and (A14), respectively. Preferred estimates of FGE (denoted *g*) and its variance are given by:

$$\hat{g} = \hat{f}_1^* + \hat{f}_2^*$$

and

$$\hat{\sigma}_{\hat{g}}^2 = \hat{\sigma}_{\hat{f}_1^*}^2 + \hat{\sigma}_{\hat{f}_2^*}^2 - 2\frac{\hat{f}_1^* \hat{f}_2^*}{R_T} \ ,$$

where $\hat{f}_1^*$ and $\hat{f}_2^*$ denote bias-corrected passage-rate estimates (equation A12) for NFB and Unit 13, respectively, with corresponding variance estimates $\hat{\sigma}_{f_1^*}^2$ and $\hat{\sigma}_{f_2^*}^2$ (equation A14), and R_T is the number of treatment fish released. Given multiple replicate experiments, the preferred estimator of combined FGE is the weighted mean (equation A18) using weights equal to the inverse of the coefficient of variation (CV) of each replicate FGE estimate.

Derivation of estimators for FGE

The following derivations are largely based on methods and notation described in PGE (2007). A given FGE experiment consisted of a single "treatment" release and two "calibration" releases. For calibration releases, fish were released directly into a given bypass (NFB or Unit 13) to estimate detection probabilities. Treatment fish were released into the forebay upstream of the turbines and bypasses to assess passage rates. Treatment and calibration fish were released simultaneously in small batches over a period of one to two hours in an attempt to ensure representative coverage of detection probabilities among groups. Although we are interested in passage rates among the two bypasses (NFB and Unit 13), it is useful to begin with single-bypass estimates before generalizing to the dual-bypass case.

<u>Single bypass scenario</u>

For the single bypass case, define as follows:

R_C = number of calibration fish released

R_T = number of treatment fish released

p = detection probability for the bypass

f = probability of treatment fish using the bypass

c = number of R_C detected in the bypass

t = number of R_T detected in the bypass

n = number of (unobserved) R_T using the bypass

The number of treatment fish detected (t) in the bypass is a combination of two random processes: the probability of bypass passage (f) and the probability of subsequent detection (p). Each is a binomial process, whereby the distribution of t is conditional on n:

$n \sim \text{binomial}(R_T, f)$,

$t|n \sim \text{binomial}(n, p)$.

The unconditional distribution for t is itself a binomial distribution, denoted as

$t \sim \text{binomial}(R_T, fp)$.

The expectation and variance of t are (Mood et al. 1974, p. 89):

(A1) $\text{E}[t] = R_T fp$

(A2) $\text{V}[t] = R_T fp(1 - fp)$.

The calibration test also follows a binomial distribution:

$c \sim \text{binomial}(R_C, p)$

with expectation and variance

(A3) $\text{E}[c] = R_C p$

(A4) $\text{V}[c] = R_C p\,(1 - p)$.

From equations (A1) and (A3), an expression for fish passage rate (f) as a function of the random variables t and c is given by

(A5) $$f = \frac{E[t]}{R_T\,p} = \frac{R_C}{R_T}\frac{E[t]}{E[c]}\ .$$

An intuitive estimate of f is obtained by substituting observations of t and c into equation (A5):

(A6) $$\hat{f} = \frac{R_C}{R_T}\frac{t}{c}\ .$$

The theoretical variance of $\hat{f}$ is a function of the variance of the ratio of t and c:

(A7) $$V[\hat{f}] = \left(\frac{R_C}{R_T}\right)^2 V\left[\frac{t}{c}\right].$$

Given that *t* and *c* arise from independent releases (i.e., they are not correlated), an approximate variance formula for this ratio is given by (Mood et al. 1974, p. 181):

(A8) $$V\left[\frac{t}{c}\right] \cong \left(\frac{\mu_t}{\mu_c}\right)^2 \left(\frac{V[t]}{\mu_t^2} + \frac{V[c]}{\mu_c^2}\right),$$

where $u_t \equiv E[t]$ and $u_c \equiv E[c]$. Substituting equations (A1)-(A4) and (A8) into equation (A7) yields

(A9) $$\begin{aligned} V[\hat{f}] &= \left(\frac{R_C}{R_T}\right)^2 \left(\frac{R_T fp}{R_C p}\right)^2 \left(\frac{R_T fp(1-fp)}{(R_T fp)^2} + \frac{R_C p(1-p)}{(R_C p)^2}\right) \\ &= f^2 \left(\frac{(1-fp)}{R_T fp} + \frac{(1-p)}{R_C p}\right) \\ &= f^2 \left(\frac{1}{E[t]} - \frac{1}{R_T} + \frac{1}{E[c]} - \frac{1}{R_C}\right). \end{aligned}$$

Substituting the estimate of *f* and observations *t* and *c* into equation (A9) yields the following variance estimator for $\hat{f}$:

(A10) $$\hat{\sigma}_{\hat{f}}^2 = \hat{f}^2 \left(\frac{1}{t} - \frac{1}{R_T} + \frac{1}{c} - \frac{1}{R_C}\right).$$

The estimators for $\hat{f}$ (equation A6) and $\hat{\sigma}_{\hat{f}}^2$ (equation A10) are the same estimators derived and used in previous evaluations of FGE (e.g., ; PGE 2007; Interim Reports Exhibit B and C). The key assumptions of the model include (PGE 2007): (1) all fish have independent fates; (2) detection probabilities are the same for calibration fish and treatment fish; and (3) all treatment fish migrate through the forebay (i.e., no post-release mortality occurs).

However, it is anticipated that $\hat{f}$ would be a biased estimator of *f* because it is a function of the ratio of *t* and *c*. Specifically, with *t* and *c* uncorrelated, the expectation of $\hat{f}$ is approximated by (Mood et al. 1974, p. 181):

(A11) $$E[\hat{f}] \cong \frac{R_C}{R_T} E\left[\frac{t}{c}\right] = \frac{R_C}{R_T}\frac{\mu_t}{\mu_c}\left(1 + \frac{V[c]}{\mu_c^2}\right).$$

Thus, we expect "positive bias" in $\hat{f}$ equivalent to the right-hand term in equation (A11) (i.e., compare with equation A5). An approximately unbiased estimate of *f* subtracts this term, which, given equations (A4) and (A11), results in the following "bias-corrected" estimator:

$$\text{(A12)} \quad \hat{f}^* = \frac{R_C}{R_T}\frac{t}{c}\left(1 - \frac{1}{c} + \frac{1}{R_C}\right).$$

The theoretical variance of $\hat{f}^*$ is given by

$$\text{(A13)} \quad \mathrm{V}[\hat{f}^*] = \left(\frac{R_C}{R_T}\right)^2 \mathrm{V}\left[\frac{t}{c}\left(1 - \frac{1}{c} + \frac{1}{R_C}\right)\right].$$

Solving for the variance term in equation (A13) via the Delta Method (e.g., Mood et al. 1974, p. 181) gives the following variance estimator for $\hat{f}^*$:

$$\text{(A14)} \quad \hat{\sigma}^2_{\hat{f}^*} = \left(\hat{f}^*\right)^2\left[\frac{1}{t} - \frac{1}{R_T} + \left(\frac{1}{c} - \frac{1}{R_C}\right)\left(1 - \frac{2}{c} + \frac{1}{R_C}\right)^2 \Big/ \left(1 - \frac{1}{c} + \frac{1}{R_C}\right)^2\right].$$

In general, estimates $\hat{f}$ and $\hat{f}^*$ will be very similar when estimates of detection probabilities are high and/or precise (i.e., biases in $\hat{f}$ will be proportional to the variance of *c*; see equation A11).

Dual bypass scenario

In the dual bypass case, the overall fish guidance efficiency (FGE) is the sum of the fish passage rates (f_1 and f_2) through two bypasses (denoted by subscripts 1 and 2). Independent calibration tests are conducted for each bypass using releases denoted R_1 and R_2. The distributions of treatment detections (t_1 and t_2) are conditional on multinomial distributions for n_1 and n_2:

n_1 and n_2 ~ multinomial(R_T, f_1, f_2, 1-f_1-f_2),

$t_1|n_1$ ~ binomial(n_1, p_1),

$t_2|n_2$ ~ binomial(n_2, p_2).

The unconditional distributions for t_1 and t_2 are simply multinomial distributions combining the probabilities of passage and detection:

t_1 and t_2 ~ multinomial(R_T, f_1p_1, f_2p_2, 1-f_1p_1-f_2p_2).

The expectations and variances of t_1 and t_2 are given by equations (A1) and (A2) (i.e., the binomial case with variables subscripted by 1 and 2 where appropriate), while the covariance between t_1 and t_2 is given by (Mood et al. 1974, p. 197):

$$\text{(A15)} \quad \mathrm{Cov}[t_1, t_2] = -R_T\,(f_1 p_1)(f_2 p_2).$$

Again, each calibration test follows a binomial distribution with expectations and variances for c_1 and c_2 given by equations (A3) and (A4), subscripted appropriately. Using the uncorrected estimate $\hat{f}$ (equation A6), the estimate of overall FGE (denoted g) is given by

$$\text{(A16)} \quad \hat{g} = \hat{f}_1 + \hat{f}_2 = \frac{R_1}{R_T}\frac{t_1}{c_1} + \frac{R_2}{R_T}\frac{t_2}{c_2} \ .$$

The variance estimator for FGE follows from the expression for the variance of a sum of two random variables (e.g., Mood et al. 1974, p. 179) and equation (A15):

$$\text{(A17)} \quad \begin{aligned} \hat{\sigma}_{\hat{g}}^2 &= \hat{\sigma}_{\hat{f}_1}^2 + \hat{\sigma}_{\hat{f}_2}^2 + 2\text{Cov}[\hat{f}_1, \hat{f}_2] \\ &= \hat{\sigma}_{\hat{f}_1}^2 + \hat{\sigma}_{\hat{f}_2}^2 + 2\frac{R_1}{R_T c_1}\frac{R_2}{R_T c_2}\text{Cov}[t_1, t_2] \\ &= \hat{\sigma}_{\hat{f}_1}^2 + \hat{\sigma}_{\hat{f}_2}^2 - 2\frac{\hat{f}_1 \hat{f}_2}{R_T}. \end{aligned}$$

The biased-corrected estimators $\hat{g}^*$ and $\hat{\sigma}_{\hat{g}^*}^2$ have the same forms as equations (A16) and (A17), but with $\hat{f}$ and $\hat{\sigma}_{\hat{f}}^2$ replaced by $\hat{f}^*$ and $\hat{\sigma}_{\hat{f}^*}^2$. Confidence intervals (CI) for $\hat{g}$ (or $\hat{g}^*$) could be derived using several methods. The simplest approach is to assume that the sampling distribution of $\hat{g}$ is approximately normal, such that a 95% CI would be constructed as $\hat{g} \pm 1.96\hat{\sigma}_{\hat{g}}$. Other options (not explored here) include confidence intervals based on likelihood theory or bootstrapping.

Note that the above variance estimator (A17) differs from that presented in PGE (2007). Unfortunately, there are a couple of errors in equation (9) of PGE (2007, p. 16) that result in much greater variances than warranted. First, in the final term of PGE equation (9), the component $(R_{Ti}G_iF_ip_{2i})^2$ should be $(R_{Ti}G_i(1-F_i)p_{2i})^2$. This term was correct in the "Appendix B derivation" of PGE (2007; p. 46) but was incorrect in PGE equation (9). Second, in the "Appendix B derivation" of PGE (2007), important terms were inadvertently omitted as the derivation proceeded. Specifically, in the evaluation of

$$E\left(\frac{f_1^2(1-p_1)}{R_{C1}p_1^3} + \frac{f_2^2(1-p_2)}{R_{C2}p_2^3}\right) \text{(last term on the bottom of p. 45 of PGE 2007)}$$

the terms $(1 - p_1)$ and $(1 - p_2)$ were subsequently dropped. Thus, the last two terms of the final formula (p. 46 of PGE 2007) should read:

$$Var(\hat{G}) = \quad \cdots \quad + (1-p_1)\left(\frac{R_T GFp_1(1-GFp_1) + (R_T GFp_1)^2}{R_T^2 R_{C1} p_1^3}\right)$$
$$+ (1-p_2)\left(\frac{R_T G(1-F)p_2(1-G(1-F)p_2) + (R_T G(1-F)p_2)^2}{R_T^2 R_{C2} p_2^3}\right)$$

These corrections to PGE equation (9) result in variance estimates that are almost identical to those computed using (A17) above. However, slight differences still arise due to the different methods of derivation. The approach used in the "Appendix B derivation" of PGE (2007), which evaluated "variances in stages" (i.e., used the conditional variance formula), was unnecessarily complex. The simple derivation of (A17) above is preferred.

In summary, the estimators derived here differ from those of PGE (2007) in two important ways. First, given the simulation analyses below, the preferred estimators for FGE use the bias-corrected passage-rate estimates, $\hat{f}_1^*$ and $\hat{f}_2^*$ (equation A12) for NFB and Unit 13, respectively, with corresponding variance estimates $\hat{\sigma}^2_{f_1^*}$ and $\hat{\sigma}^2_{f_2^*}$ (equation A14). Second, the variance estimator (A17) was used for the dual-bypass case to estimate the variance of a given FGE estimate.

Combining replicate experiments

When a series of k replicate experiments are conducted under similar operating conditions, a combined estimate of FGE is desired. An overall (minimum-variance) estimate of FGE could be obtained by pooling data across the k trials (i.e., as though they came from a single experiment). However, such pooling would only be valid if detection probabilities (p_1 and p_2) and passage rates (f_1 and f_2) were essentially constant across trials, otherwise, estimates of pooled FGE would likely be biased. Because there is clear evidence that detection probabilities vary across replicates, pooling of all replicate data is not advisable. An alternative approach would be to assess differences in detection probabilities among replicates, and pool only those replicates that had statistically similar detection probabilities. However, this approach is also not advisable because some replicates would be excluded from the analysis, which is highly selective and unnecessary.

Alternatively, an approach that incorporates all data and requires no assumptions regarding constancy of detection probabilities is to compute a weighted mean for FGE across the k replicate experiments:

(A18) $$\hat{\bar{g}} = \sum_{i=1}^{k} w_i \hat{g}_i \bigg/ \sum_{i=1}^{k} w_i \ ,$$

where w_i denotes the weight applied to the ith replicate. The purpose of weighting is to account for the uncertainty in each replicate estimate of FGE. By providing greater weight to more precise estimates of FGE, the resulting weighted mean should be more precise than a simple average that assumes no weighting. Ideally, the estimates and their corresponding weights in equation (A18) should be independent (uncorrelated).

The appropriate variance estimator for $\hat{\bar{g}}$ depends on assumptions about the actual distribution of FGE. If the true FGE is assumed to be "fixed" or constant across replicates (i.e., for a given operating condition, there is no variability in FGE regardless of day, season, etc.), then all variation in replicate estimates of FGE (i.e., $\hat{g}_i$) is due to sampling error. In this case, the variance of the weighted mean is given by:

$$\hat{\sigma}^2_{\hat{\bar{g}}} = \sum_{i=1}^{k} w_i^2 \hat{\sigma}^2_{\hat{g}_i} \Bigg/ \left(\sum_{i=1}^{k} w_i \right)^2 .$$

In contrast, if the true FGE varies over time (i.e., values of FGE may differ among replicate tests and follow some distribution with a common mean and variance), then actual variances will be greater than assumed by the above equation. For the case of variable FGE, an appropriate variance estimator is (e.g., Neter et al. 1996, p. 403):

$$(19) \qquad \hat{\sigma}^2_{\hat{\bar{g}}} = \sum_{i=1}^{k} w_i \left(\hat{g}_i - \hat{\bar{g}} \right)^2 \Bigg/ (k-1) \sum_{i=1}^{k} w_i .$$

Equations (A18) and (A19) are equivalent to estimates obtained via weighted least squares for an intercept-only regression model. Note that when all weights (w_i) are set to the same value, equations (A18) and (A19) reduce to the standard expressions for the mean and its variance under no weighting. Under the assumption of normality, the weighted (or unweighted) estimates ($\hat{\bar{g}}$) follow the *t*-distribution with *k*-1 degrees of freedom.

Examination of the data, in particular for Chinook, suggested that replicate FGE estimates contain greater variation than would be expected due to sampling error alone. Thus, the more conservative variance estimator (A19) is used to estimate the variance of the weighted mean.

A standard practice is to assign weights equal to the inverse of the variance of each data point (i.e., $w_i = 1/\hat{\sigma}^2_{\hat{g}_i}$), which in theory provides a minimum-variance estimator of the mean. However, variance estimates of passage rates (and hence, of $\hat{g}_i$) are proportional to the estimates themselves (e.g., equations A12 and A14). Thus, across the sampling distribution for a given experiment, larger estimates of FGE will tend to have higher variances. Such dependencies between data and weights may result in biased estimates. Consequently, alternative weighting schemes may yield estimates with preferred statistical properties. In the simulation analyses below, several alternatives are examined, including weights equal to the inverse of the coefficient of variation (CV) (i.e., $w_i = \hat{g}_i / \hat{\sigma}_{\hat{g}_i}$), the inverse of CV^2 (e.g., Smith et al. 2006), and weights equal to treatment release size (R_T).

As discussed in Appendix B, separate estimates of passage rate for each bypass may be desired to compute overall survival ("Powerhouse Performance"). In this context, total FGE is separated into its two components (NFB and Unit 13 passage rates) to provide bypass-specific survivals, which are then summed to estimate combined bypass survival. It is appropriate in this case to compute weighted means for passage rates using the *same* weights (w_i) defined for FGE. Weighted means ($\hat{\bar{f}}_1$ and $\hat{\bar{f}}_2$) and their variances ($\sigma^2_{\hat{\bar{f}}_1}$ and $\sigma^2_{\hat{\bar{f}}_2}$) for passage rates are estimated as in equations (A18) and (A19), while the weighted covariance between $\hat{\bar{f}}_1$ and $\hat{\bar{f}}_2$ is estimated by:

$$\text{(A20)} \quad \hat{\sigma}_{\hat{\bar{f}}_1 \hat{\bar{f}}_2} = \sum_{i=1}^{k} w_i \left(f_{1i} - \hat{\bar{f}}_1 \right)\left(f_{2i} - \hat{\bar{f}}_2 \right) \Big/ (k-1)\sum_{i=1}^{k} w_i \ .$$

Simulation analyses

To have confidence in estimates derived from a single experiment, it is important to examine the accuracy and precision of estimates for FGE, as well as confidence intervals based on the normal approximation. The variance estimators for FGE derived above involve approximations for ratios based on the Delta method, which may be poor in some circumstances. In addition, when computing confidence intervals, the assumption of normality may be inappropriate for the discrete binomial and multinomial processes underlying estimates of FGE, especially when sample sizes are small.

More importantly, we need to examine the accuracy, precision, and confidence intervals of weighted means of FGE that combine data across replicate experiments. Ultimately, these estimates will be used to determine overall project survival. In the following analyses, we conduct simulations consistent with observed data to examine the validity of estimates for single and multiple experiments.

<u>Single experiment</u>

To examine single-experiment estimates (dual-bypass case), simulations were conducted for five sample sizes (N = 200, 400, 600, 800, 1000) and two specified detection probabilities ($p_1 = p_2 = p = 0.3$ and 0.8). The total sample size (N) was distributed among R_T, R_1, and R_2 using a 50/25/25 percent allocation, which is consistent with most experimental data (note that among Chinook and steelhead FGE tests, only one test for Chinook had $N < 200$; i.e., Test 7, Table 1, $N = R_1 + R_2 + R_T = 189$). Total passage rate through the bypasses (FGE = g) was assumed to be 0.97, with $f_1 = 0.95g$ and $f_2 = 0.05g$. This is consistent with observed experimental data for Chinook juveniles. For each specification of N and p, ten thousand Monte Carlo trials were conducted in which observed variables t and c were generated using the appropriate multinomial and binomial distributions described above. Estimates $\hat{g}$ and $\hat{\sigma}_{\hat{g}}$, and the bias-corrected versions $\hat{g}^*$ and $\hat{\sigma}_{\hat{g}^*}$, were then compared across simulations. In addition, coverage was assessed for approximate 95% confidence intervals for $\hat{g}^*$ that were constructed assuming normality (i.e., $\hat{g}^* \pm 1.96\, \hat{\sigma}_{\hat{g}^*}$).

Results

Estimates $\hat{g}$ were particularly biased for small sample sizes and low detection probabilities (i.e., N = 200 and p = 0.3; open circles in Figure A1). Estimates $\hat{g}^*$ were very accurate across conditions (solid circles in Figure A1). In addition, the sampling distributions of $\hat{g}$ were more variable than $\hat{g}^*$, especially for small N and p (Figure A2; "+" = standard deviation of $\hat{g}$ and "x" = standard deviation of $\hat{g}^*$). Estimates of standard errors (SE) for both $\hat{g}$ and $\hat{g}^*$ were very accurate (Figure A2; $\hat{\sigma}_{\hat{g}}$ = open circles and $\hat{\sigma}_{\hat{g}*}$ = solid circles). In sum, both estimators were very accurate when simulated sample sizes were large and detection probabilities were high. However, given that the bias-corrected estimator $\hat{g}*$ was more accurate and precise across simulated conditions, it will be used in all subsequent analyses. These simulation results indicate that when model assumptions are valid, the bias-corrected versions $\hat{g}*$ and $\hat{\sigma}_{\hat{g}*}$ are essential unbiased, that is, they contain no "estimator bias."

Confidence intervals for $\hat{g}*$ derived assuming normality had coverage probabilities that were more stringent than desired for the lower 95% CI bound, and conversely, less than desired for the upper bound (Table A1). In other words, when the CI failed to include the true value of *g* (FGE), it was typically because *g* exceeded the upper bound of the confidence interval. Differences between actual and desired coverage probabilities were greatest for small *N* and *p* (Table A1), and resulted from skewed sampling distributions. Other methods for deriving confidence intervals based on likelihood theory or bootstrapping could be explored. However, single-experiment estimates are not of primary concern here, and furthermore, confidence intervals based on the assumption of normality appear to provide conservative coverage of the lower bound for *g* (Table A1), which is an acceptable direction for error given that low values of *g* pose the greatest risk to fish survival (i.e., lower FGE implies a greater proportion of juveniles travel through the turbines).

Table A1. Simulated coverage probabilities for the lower and upper bounds of 95% confidence intervals derived for $\hat{g}*$ assuming normality (across 10,000 Monte Carlo simulations). The desired coverage probabilities are 0.025 (lower bound) and 0.975 (upper bound). *N* = total release number; *p* = detection probability.

	p = 0.3		*p* = 0.8	
N	Lower	Upper	Lower	Upper
200	0.000	0.919	0.006	0.953
400	0.003	0.940	0.012	0.958
600	0.004	0.949	0.013	0.961
800	0.007	0.951	0.013	0.963
1000	0.010	0.951	0.018	0.963

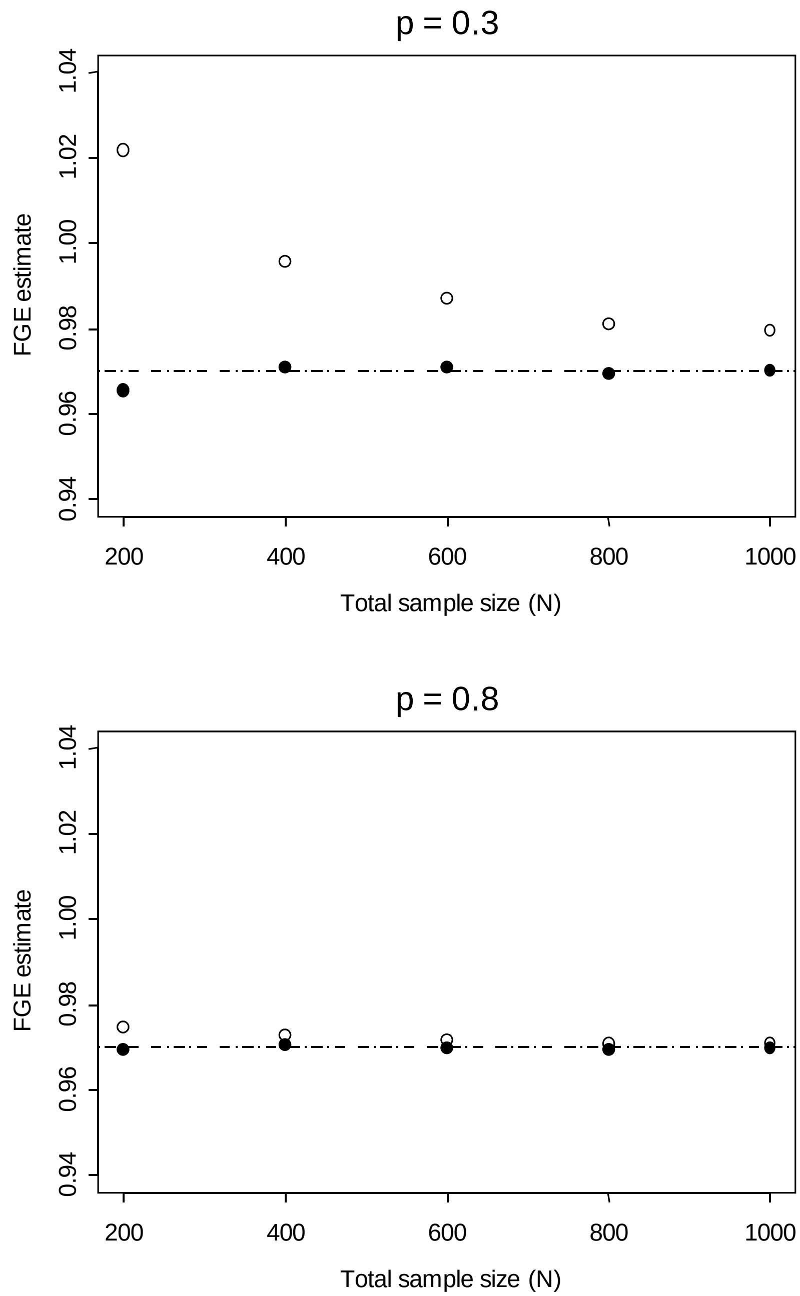

Figure A1. Mean values across 10,000 Monte Carlo simulations of estimates $\hat{g}$ (open circles) and $\hat{g}*$ (solid circles) when detection probabilities (p) equaled 0.3 (upper panel) and 0.8 (lower panel).

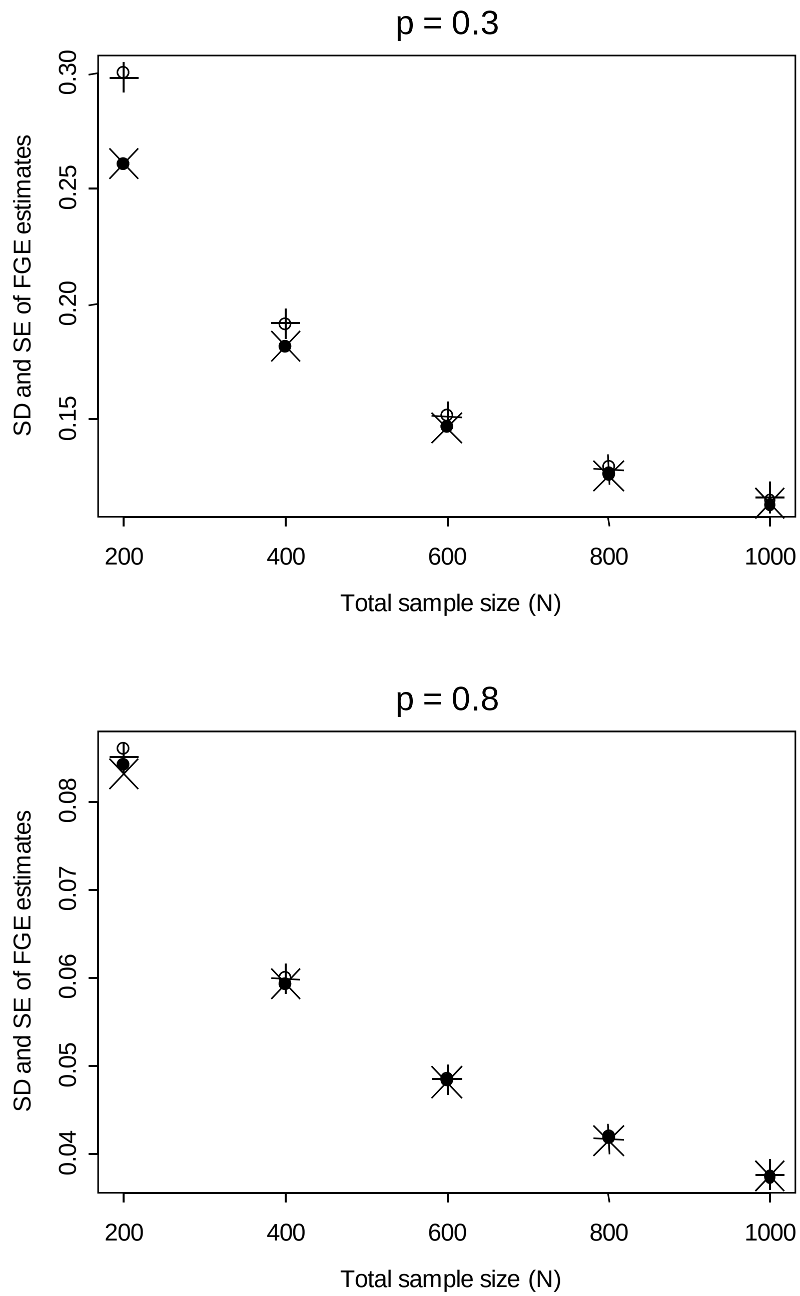

Figure A2. Standard deviations (SD) of the distributions for $\hat{g}$ ("+") and $\hat{g}*$ ("x") across 10,000 Monte Carlo simulations, and mean values of the estimated standard errors (SE) for $\hat{g}$ (open circles) and $\hat{g}*$ (solid circles).

Multiple replicate experiments

To examine estimates derived across replicate experiments, simulations were conducted based on releases for Chinook juveniles (k = 19 replicates; Table 1) and steelhead juveniles (k = 8 replicates; Table 2). Estimates of mean FGE for each species are shown in Table A2. For each simulated experiment i, actual values for R_T, R_1, and R_2 were used, and detection probabilities (p_1 and p_2) were set equal to the observed estimates (Tables 1 and 2).

Simulations were conducted with values for passage rates consistent with observed data. For Chinook, mean passage rates were set to $g = 0.96$, $f_1 = 0.94g$, and $f_2 = 0.06g$. For steelhead, $g = 0.99$, $f_1 = 0.98g$, and $f_2 = 0.02g$. For both species, FGE was assumed to be variable, where g_i followed a beta distribution with the specified means above and standard deviations of 0.064 for Chinook and 0.024 for steelhead (values derived from data). Thus, values of g_i differed among replicates as well as simulation trials.

Ten thousand Monte Carlo trials were conducted. Five estimators of mean FGE (equation A18) were compared: means based on inverse-variance weights, inverse-CV^2 weights, inverse-CV weights, R_T weights, and no weights (i.e., the standard mean). Variances of each mean were estimated using equation (A19). In all cases, 95% confidence intervals were constructed based on the t-distribution with k-1 degrees of freedom.

Table A2. Estimated means, standard errors (SE), and lower (LCI) and upper (UCI) 95% confidence intervals for FGE across the 19 replicate tests for Chinook (Table 1) and eight replicates for steelhead (Table 2).

Species	Weighting	Mean $\hat{\bar{g}}$	SE($\hat{\bar{g}}$)	LCI	UCI
Chinook	Inverse-variance	0.977	0.0162	0.943	1.011
	Inverse-CV^2	0.987	0.0145	0.956	1.017
	Inverse-CV	0.973	0.0167	0.938	1.008
	R_T	0.981	0.0146	0.950	1.012
	None	0.956	0.0183	0.918	0.995
Steelhead	Inverse-variance	1.035	0.0143	1.001	1.069
	Inverse-CV^2	1.037	0.0135	1.006	1.069
	Inverse-CV	1.038	0.0140	1.005	1.071
	R_T	1.043	0.0135	1.011	1.075
	None	1.040	0.0143	1.006	1.074

Results

The following results are limited to those for inverse-variance weights (the typical weighting approach), inverse-CV weights, and for comparison, no weights (i.e., the standard mean). Results for inverse-CV^2 and R_T weights were similar to those for inverse-variance weights.

When evaluating the performance of a given estimator, we want to minimize bias and variance, and achieve desired coverage probabilities for confidence intervals (i.e., closely approximate the sampling distribution). For simulations of Chinook releases, results generally favored the weighted mean based on inverse-CV weights (Table A3). First, note that all estimates ($\hat{\bar{g}}$) of mean FGE (g = 0.96) were quite accurate, although inverse-variance means were biased slightly low (Table A3). The next consideration is the variability of estimates, measured here by the standard deviation (SD) of their sampling distributions. For Chinook simulations, inverse-CV means were considerable less variable (SD($\hat{\bar{g}}$) = 0.016) than the other means (SD($\hat{\bar{g}}$) = 0.020) (Table A3). The third consideration is how well standard errors (SE) of a given mean and corresponding confidence intervals were estimated. Coverage probabilities of 95% CIs were similar across methods for Chinook simulations, providing slightly less coverage than desired for the lower CI bound (Table A3). In sum, for Chinook data, overall performance was determined best for inverse-CV means because estimates where considerably less variable.

For simulations based on steelhead data, similar results were found for inverse-variance and inverse-CV means (Table A3). Given the preference for inverse-CV means based on Chinook data, this estimator was used to for both species when estimating mean FGE or passage rates for use in estimation of overall survival ("Powerhouse Performance").

Table A3. Summary of simulated estimates of mean FGE ($\hat{\bar{g}}$) across 10,000 Monte Carlo trials. Simulations were based on 19 replicate experiments for Chinook juveniles (Table 1) with "true" g = 0.96 and eight replicates for steelhead (Table 2) with g = 0.99. SD = standard deviation of the 10,000 estimates of $\hat{\bar{g}}$; SE($\hat{\bar{g}}$) = mean of the 10,000 estimates of the standard error of $\hat{\bar{g}}$; "Lower" = estimated coverage probability of the lower 95% CI for $\hat{\bar{g}}$ (the desired coverage is 0.025); "Upper" = coverage probability of the upper 95% CI (the desired coverage is 0.975).

Species	Weighting	Mean $\hat{\bar{g}}$	SD($\hat{\bar{g}}$)	SE($\hat{\bar{g}}$)	Lower	Upper
Chinook	Inverse-variance	0.954	0.020	0.016	0.053	0.962
	Inverse-CV	0.962	0.016	0.017	0.049	0.993
	None	0.960	0.020	0.019	0.039	0.986
Steelhead	Inverse-variance	0.987	0.014	0.013	0.024	0.976
	Inverse-CV	0.990	0.014	0.014	0.028	0.984
	None	0.990	0.016	0.015	0.029	0.982

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Appendix B

Derivation of Statistical Estimators for Overall Survival (Powerhouse Performance)

Derivation of Statistical Estimators for Overall Survival (Powerhouse Performance)

Overall survival is determined by fish passage rates through alternative routes and the corresponding survival rates experienced by juveniles in each route. Two approaches are considered. Under the first approach, two alternatives for fish passage are assumed whereby fish travel either through the bypasses (with passage probability = g and survival = s_1) or through the turbines (with passage probability = 1 - g and survival = s_2). For this combined-bypasses scenario, overall survival (S) is given by

(B1) $$S = gs_1 + (1 - g)s_2 .$$

Assuming that estimates of g, s_1, and s_2 are independent of each other, substituting these estimates into (B1) provides an unbiased estimator of S:

(B2) $$\hat{S} = \hat{g}\hat{s}_1 + (1 - \hat{g})\hat{s}_2 .$$

The variance of S can expressed as:

(B3) $$\begin{aligned} V[S] &= V[gs_1] + V[(1-g)s_2] + 2\operatorname{cov}[gs_1, (1-g)s_2] \\ &= V[gs_1] + V[(1-g)s_2] - 2s_1 s_2 V[g] \end{aligned} .$$

For product terms, the formula for the exact variance differs from the formula for the unbiased estimate (Goodman 1960), and we are interested in the latter. To simplify notation, $v[x]$ is used to denote the variance estimate of x. Expressing the variances of the products in (B3) as unbiased estimates (Goodman 1960) gives:

(B4) $$v[S] = g^2 v[s_1] + s_1^2 v[g] - v[g]v[s_1] + (1-g)^2 v[s_2] + s_2^2 v[g] - v[g]v[s_2] - 2s_1 s_2 v[g] .$$

Simplifying (B4) yields the following variance estimator for estimate S given estimates of g, s_1, and s_2:

(B5) $$v[\hat{S}] = \left(\hat{g}^2 - v[\hat{g}]\right)v[\hat{s}_1] + \left((1-\hat{g})^2 - v[\hat{g}]\right)v[\hat{s}_2] + (\hat{s}_1 - \hat{s}_2)^2 v[\hat{g}] .$$

Under the second approach, the two bypasses (NFB and Unit 13) are treated separately with respective passage rates (f_1 and f_2) and survival rates (s_1 and s_2). Fish travel through the turbines with passage probability = 1 - f_1 - f_2 and survival = s_3. For this separate-bypasses scenario, overall survival (S) is given by

(B6) $$S = f_1 s_1 + f_2 s_2 + (1 - f_1 - f_2)s_3 .$$

Assuming that estimates of passage rates are independent of estimates of survival rates, substituting these estimates into (B6) provides an unbiased estimator of S:

(B7) $$\hat{S} = \hat{f}_1\hat{s}_1 + \hat{f}_2\hat{s}_2 + (1 - \hat{f}_1 - \hat{f}_2)\hat{s}_3 .$$

The variance of S (equation B6) can expressed as:

(B8)
$$V[S] = V[f_1 s_1] + V[f_2 s_2] + V[(1 - f_1 - f_2)s_3] + 2\,\mathrm{cov}[f_1 s_1, f_2 s_2] + 2\,\mathrm{cov}[f_1 s_1, (1 - f_1 - f_2)s_3] + 2\,\mathrm{cov}[f_2 s_2, (1 - f_1 - f_2)s_3] .$$

Each term in (B8) can be expressed in terms of the variance estimate for S as follows:

(B9)
$$\begin{aligned}
&V[f_1 s_1] \to \quad f_1^2 v[s_1] + s_1^2 v[f_1] - v[f_1]v[s_1] \\
&V[f_2 s_2] \to \quad f_2^2 v[s_2] + s_2^2 v[f_2] - v[f_2]v[s_2] \\
&V[(1 - f_1 - f_2)s_3] \to \quad (1 - f_1 - f_2)^2 v[s_3] + \left(s_3^2 - v[s_3]\right)\left(v[f_1] + v[f_2] + 2v[f_1, f_2]\right) \\
&2\,\mathrm{cov}[f_1 s_1, f_2 s_2] \to \quad 2 s_1 s_2 v[f_1, f_2] \\
&2\,\mathrm{cov}[f_1 s_1, (1 - f_1 - f_2)s_3] \to \quad -2 s_1 s_3 \left(v[f_1] + v[f_1, f_2]\right) \\
&2\,\mathrm{cov}[f_2 s_2, (1 - f_1 - f_2)s_3] \to \quad -2 s_2 s_3 \left(v[f_2] + v[f_1, f_2]\right)
\end{aligned}$$

where $v[f_1 , f_2]$ denotes the covariance estimate for f_1 and f_2. Combining and simplifying the right-hand terms of (B9) yields the following variance estimator given estimates of f_1, f_2, s_1, s_2 and s_3:

(B10)
$$v[\hat{S}] = \hat{f}_1^2 v[\hat{s}_1] + \hat{f}_2^2 v[\hat{s}_2] + (1 - \hat{f}_1 - \hat{f}_2)^2 v[\hat{s}_3] + \left((\hat{s}_1 - \hat{s}_3)^2 - v[\hat{s}_1] - v[\hat{s}_3]\right)v[\hat{f}_1] + \left((\hat{s}_2 - \hat{s}_3)^2 - v[\hat{s}_2] - v[\hat{s}_3]\right)v[\hat{f}_2] + 2(\hat{s}_3^2 + \hat{s}_1\hat{s}_2 - \hat{s}_1\hat{s}_3 - \hat{s}_2\hat{s}_3 - v[\hat{s}_3])v[\hat{f}_1, \hat{f}_2] .$$

Confidence intervals (CI) for $\hat{S}$ are derived by assuming that the sampling distribution of $\hat{S}$ is approximately normal, such that a 95% CI is constructed as $\hat{S} \pm 1.96\, v[\hat{S}]$.

References

Goodman, L.A. 1960. On the exact variance of products. Journal of the American Statistical Association, 55: 708-713.

INTERIM REPORTS

Exhibit A

Sullivan Powerhouse Evaluation of Bypass System Fish Guidance Efficiency (FGE) and Survival Performance, 2007

Exhibit A

INTERIM REPORT

T.W. Sullivan Powerhouse Evaluation of Bypass System Fish Guidance Efficiency (FGE) And Survival Performance

2007

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December 2007

Exhibit A

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1.0 INTRODUCTION AND BACKGROUND

The Willamette Falls Hydroelectric project (FERC No. 2233) is located on the Willamette River at river mile 26.2, approximately 5 miles south of Portland, Oregon. Willamette Falls is a naturally occurring, 40-ft-high horseshoe shaped basalt rock formation with a low concrete gravity dam along its entire crest (Figure 1). On 8 December 2005, Portland General Electric (PGE) was issued an Order by the Federal Energy Regulatory Commission (FERC) approving the Settlement Agreement and issuing a New License for the Willamette Falls Project. Contained in the new FERC license is "Ordering Paragraph E" which makes the conditions submitted by the National Marine Fisheries Service (NMFS) under section 18 of the Federal Power Act a requirement of the license (Appendix B to the License). Conditions in Appendix B stipulate downstream juvenile salmonids passage protection goals of 98% survival for downstream migrating salmonids as they pass through the structures related to the modifications at the T.W. Sullivan Hydroelectric project. This progress report is an overview and summary of the progress made towards testing Fish Guidance Efficiency (FGE) at the T.W. Sullivan plant with the newly constructed siphon bypass or "north fish bypass" (NFB) in operation.

Since the forebay of the T.W. Sullivan plant is oriented parallel with river flow, the fish bypass system at the project is designed to operate as a louver system. Fish entering the forebay are guided along the intake racks installed upstream of the turbine intakes and exit the forebay through either the newly constructed NFB or through the existing Unit 13 bypass. The purpose of the NFB is to provide an additional opportunity for non-turbine downstream passage of fish that have entered the forebay. The NFB is located adjacent to Unit 13, and was designed to work independently or in conjunction with the existing Eicher screen bypass system (Figure 2). The NFB has a design flow capacity of approximately 500 cfs.

The objective of this part of the post construction evaluation of the NFB and Unit 13 fish bypasses is to estimate FGE of hatchery reared spring Chinook *Oncorhynchus tshawytscha* and steelhead *O. mykiss* smolts with both bypasses operating together as well as each bypass operating independently.

2.0 METHODS AND MATERIALS

2.1 Fish Guidance Efficiency

2.1.1 Data Collection and Antenna Calibration

Passive integrated transponder (PIT) tags were used to evaluate FGE of the NFB and the existing Unit 13 bypasses at the T.W. Sullivan powerhouse in spring and fall 2007. A PIT tag detection antenna was constructed specifically for the NFB and was installed immediately prior to this study. The newly constructed PIT tag antenna was similar to the existing antennas installed in the Unit 13 bypass downstream of the Eicher screen and just upstream of the evaluator catch tank. The NFB antenna is connected to an automated monitoring system that records the unique tag identification code as individual fish pass through the antenna. This information is combined with passage time and antenna identification (*i.e.,* NFB or Unit 13), and is then uploaded to the PTAGIS website operated by the Pacific States Marine Fisheries Commission (PSMFC), where it can be queried and downloaded for analysis.

As suggested by Skalski (2000), the PIT tag antennas were calibrated for detection efficiency prior to each test release into the forebay. Depending on the test scenario, one or both antennas were calibrated during each test by releasing fish immediately upstream of the antenna using an induction device. Calibration fish were released during the same day and in conjunction with treatment fish so that antenna noise was similar for both groups.

2.1.2 Fish Procurement and Holding

Juvenile salmonids were collected from the catch tank in the Unit 13 bypass evaluator. To increase capture rates, the evaluator was operated at night and the NFB was typically closed during periods of fish collection. A technician remained on site while the evaluator was in operation to remove debris, and to move hatchery fish designated to be tagged into a holding tank. All fish not designated to be tagged were tallied and released back into the river.

2.1.3 Fish Tagging and Release

All fish selected for tagging were anesthetized in a solution of clove oil, measured for fork length (mm), and then injected with a standard 12mm SGL TX1400 PIT tag similar to methods described in PGE (2006). Each tagged fish was scanned to verify that the tag was operational, and to establish the tag code in an electronic database so that individual fish could be later identified. Once tagged, the juvenile Chinook were returned to the holding tanks to recover, whereas steelhead smolts were immediately transferred to holding tanks near the release sites. Treatment fish designated to be released into the forebay were held overnight and typically released the following morning. [On 22 May, we released two separate groups of treatment fish, those that had been tagged and released the same day, and those that were tagged the previous day and allowed to recovery overnight, to compared possible effects of holding time on FGE]. Fish designated as calibration fish were also held overnight, but at times were held for a shorter duration depending on fish availability.

Prior to release, Chinook smolts were removed from the holding tanks and placed into 5 gallon buckets. Each bucket was supplied with a hose and continually flushed with ambient river water until they were ready to be transported to the release site. For steelhead, fish were transported in 5 gallon buckets immediately after tagging to one of two 600 gallon holding ponds located at the calibration and treatment release sites. Steelhead were transferred to a series of perforated 55 gallon trash cans submerged in the holding ponds, and held in groups of 20 overnight.

One treatment and two calibration release sites were designated for this study as described in PGE (2006). Briefly, calibration fish were released immediately upstream of each PIT tag antenna through a water-to-water release pipe and induction system. Treatment fish were released into the forebay approximately 20 feet downstream of the main head gates through one of three ports constructed into the floor (*i.e.*, Left, Middle, and Right; Figure 2). Treatment fish were released in groups of 10 to 20 fish through a four-inch diameter flex-hose reaching from the deck to just above the water surface. [On 18 May, we released approximately one-third of the treatment fish into each of the three ports to compare possible effects of release location on FGE].

2.1.4 Data Analysis

Passage data were analyzed based on two alternative likelihood models designed to estimate FGE through a single or double bypass route (PGE 2006). Both models accounted for the probability of detecting a fish (detection efficiency) at one or both antennas. The models compare these detection probabilities to the number of treatment fish released to the number of fish detected to derive an adjusted estimate of FGE. A Chi Square test of homogeneity was used to test whether the detection efficiencies of individual calibration releases could be pooled (by species) for use in the model, or if detection efficiencies from each individual trial had to be used in the analysis.

2.2 Unit 13 Bypass (Reach one – 13) Survival/Injury Study

In early May 2007, we evaluated direct survival and mortality of juvenile salmonids through the upper reach of the Unit 13 bypass similar to previous studies (PGE 1998) and as outlined in PGE 2006.

A sub-sample of smolts were randomly selected from the Unit 13 evaluator immediately following passage and were held for 48 hrs. Smolts were held in the holding tanks located at the Unit 13 bypass evaluator. Tanks were checked for fish mortalities 24 hrs and 48 hrs after passage. All fish that had died during the holding period were necropsied to assess the probable cause of death. Direct survival for each species was calculated as:

$$Survival = \left(\frac{a_i}{n_i}\right)$$

where,

a_i = is the number of fish alive after 48 hrs; and

n_i = is the total number of fish held for 48 hrs.

All specimens alive at 48 hrs were anesthetized, measured for length, and closely examined for injury, descaling, or other maladies. Maladies were categorized by type, extent, and area of body as outlined in criteria developed by NOAA Fisheries for use on the Columbia River (Appendix B). All fish alive following examination were returned to the river.

3.0 RESULTS AND DISCUSSSION

3.1 Fish Guidance Efficiency

3.1.1 Overview

Testing in spring 2007 did not commence until the performance of the new NFB PIT tag antenna was satisfactory. The initial FGE test using juvenile Chinook salmon was conducted on 29 March and was followed by five subsequent tests. All testing of Chinook salmon was completed by 27 April (Table 1). When the number of juvenile Chinook collected at the bypass declined and the number of juvenile steelhead began to increase, tagging effort shifted to steelhead. The initial FGE test using steelhead was conducted on 11 May and testing with steelhead continued through 25 May. A total of 5 releases using steelhead were conducted. Testing was suspended when water temperature reached 62˚ F.

In the spring, a total of 1,813 hatchery reared Chinook (906 treatment, 522 NFB calibration, and 385 Unit 13 calibration) and 1,398 steelhead smolts (877 treatment, 323 NFB calibration**,** and 198 Unit 13 calibration) were tagged and released to evaluate FGE (Tables 1 and 2). Juvenile Chinook were generally smaller than steelhead, with a fork length averaging 141 mm, and ranging from 104 mm to 210 mm (Table 1). Steelhead averaged 222 mm and ranged from 119 to 310 mm in length (Table 2).

Testing in the fall began when the number of juvenile Chinook smolts collected in the evaluator catch tank began to increase following upstream hatchery releases the last week in October. The initial test with juvenile Chinook in the fall occurred 7 November and was followed by two subsequent releases (Table 3). River flow increased on 17 November, which was followed by a sudden decline in the number of fish collected at the Unit 13 evaluator, and eventually to a level that precluded sampling.

In the fall, 873 hatchery Chinook smolts (470 treatment, 303 NFB calibration, and 100 Unit 13 calibration) were tagged and released to evaluate FGE (Table 3). Juvenile Chinook in the fall were larger than in the spring, averaging 174 mm and ranging from 115 to 205 in length.

3.1.2 PIT Tag Reader Efficiency

Detection efficiencies at the new NFB antenna improved during spring 2007. During the initial three releases of juvenile Chinook, detection efficiencies in the NFB were less than 70% (Table 1). This was largely attributed to spurious electrical impediment or "noise" interfering with the antenna. Sources of noise ranged from overhead electrical power lines and surrounding plant operations, to the hydraulic harmonics of water passing through the antenna itself. Several sources of noise were eventually identified and controlled.

Since initial tests using juvenile Chinook in the spring were conducted when noise levels and detection efficiencies were more erratic (ranging from 65% to 83%), the Chi-square test indicated a significant difference in the proportion of fish detected during each calibration release ($\chi^2 = 16.39$, df = 4, p = 0.003). Consequently, the calibration data for the FGE analyses using Chinook smolts through the NFB were not pooled.

Reduced noise levels improved the detection efficiency of the NFB antenna during subsequent releases of juvenile steelhead in the spring. Efficiencies were relatively consistent ranging from 92% to 100%. The Chi-square test indicated there was no significant difference in the proportion of juvenile steelhead detected during each calibration release ($\chi^2 = 3.87$, df = 3, p = 0.275), and therefore the calibration data were pooled. The more consistent detection efficiencies observed for steelhead releases were in part attributed to the lower, less erratic noise levels resulting from controlling electrical impedance. However, it is possible that improved detection efficiencies were also attributed to the larger body size of steelhead and their ability to more strongly swim against the current in the NFB. While swimming against the current, steelhead may remain within detection range of the antenna slightly longer than juvenile Chinook, thereby increasing detection probabilities. While supporting evidence for this is still only qualitative, the possible differences in detection efficiency between species should be further evaluated in the future.

The estimated detection efficiency of the Unit 13 antenna remained relatively high and consistent throughout the spring study period for both species ranging from 90% to 98% (Table 1 and Table 2). The Chi-square test indicated there was no significant difference in the proportion of fish detected during each calibration release for Chinook ($\chi^2 = 3.91$, df = 3, p = 0.271) and steelhead ($\chi^2 = 2.36$, df = 3, p = 0.501), and therefore the calibration data were pooled within species in the spring.

Due to the low number and small size of the samples released, calibration data collected were not pooled in the fall with data collected in the spring. Once further testing is completed, these data may eventually be pooled. Detection efficiency at the NFB antenna in the fall for Chinook was similar to efficiencies observed for steelhead the previous spring; ranging from 92 to 96% (Table 3). However, the detection efficiency of the 15 November test was comparatively low (78%). Unit 13 detection efficiency from the first two release groups were also consistently high (90 and 94%) and comparable to efficiencies observed in the spring. However during the 15 November test, the Unit 13 antenna was not operating correctly and no fish were detected; the reason for this is unknown at this time, but the cause may have also affected the NFB antenna efficiency.

3.1.3 Test Scenarios

We tested a variety of hydraulic and operational conditions during spring and fall 2007. Since this was the first year of testing FGE after the bypass modifications, our primary focus was on developing protocols and methodologies, evaluating the new detection system, and beginning to test the current conditions to establish a base level of information. In general, FGE estimates varied for both species and seemed to depend on the condition tested. Forebay hydraulics, flow volume through the NFB, plant operations, or a combination of these effects appeared to be among the more influential factors controlling FGE. A detailed description of each FGE test conducted in spring and fall 2007 is outlined in Appendix A. However, based on this information some general trends were identified and include:

1. ***Forebay hydraulics appeared to influence FGE*** — Visual observations indicated that the hydraulic conditions in the forebay were influenced by flow through the NFB. Large hydraulic vortices, which were present along the inner forebay racks, appeared to intensify when flow through the NFB was set at approximately 400 cfs. Similarly, turbulence in the area between the entrances of the NFB and Unit 13 appeared to increase at higher NFB flows. Initial tests using juvenile Chinook indicated that these hydraulic conditions negatively influenced FGE. For instance, passage route selection was evaluated for Chinook smolts on 4 April when the NFB flow was set at 400 cfs and the hydraulic conditions were turbulent and appeared to be unfavorable. Under these conditions, FGE was estimated to be 77%. Passage selection was then evaluated on 6 April, when flow through the NFB was reduced (~ 270 cfs) and project operations were modified to minimize the forebay vortices and reduce turbulence at the entrance of the NFB. Under these conditions, FGE increased to nearly 100%. .

2. ***When both bypasses were operating, smolts passed through the NFB at a higher rate than through the Unit13 bypass*** — In all releases conducted when both bypasses were in operation, downstream migrating juvenile Chinook and steelhead passed through the NFB at a higher rate than through the Unit 13 bypass. While some variation was observed, typically 90% of the fish that passed in the "dual bypass condition" passed through the NFB. This trend was also apparent in the number of fish collected at the Unit 13 bypass evaluator. When both bypasses were operating, the number of fish that were collected in the Unit 13 evaluator decreased. On several occasions, it was necessary to close the NFB to collect a sufficient number of test fish.

3. ***Juvenile steelhead had a higher tendency to hold upstream than Chinook smolts*** — Juvenile steelhead had a higher tendency to remain in the forebay than Chinook

smolts. This tendency was especially apparent when only one bypass was operating. During a dual-bypass test conducted on 22 May, a total of 25 juvenile steelhead remained in the forebay and were detected after the project operations were changed. During the single-bypass tests conducted on 24 May and 25 May, 53 and 45 fish, respectively, held in the forebay prior to passage and were later detected. This apparent difference may be partially due to the time allowed for steelhead to pass. During the tests in late May, project operations were changed less than 24 hours after the test fish were released. During future releases of steelhead, a minimum time period between release and changing test conditions should be established.

4. ***Release location did not appear to influence fish passage route selection and FGE*** — Similar to results described in Skalski (2000), release location did not appear to influence passage route selection and ultimately FGE for juvenile steelhead. On 18 May, approximately equal sample sizes of fish were released at each of the three release points in the forebay (*i.e.,* left, middle, and right). Overall, 228 steelhead were subsequently detected at the NFB antenna, and 16 were detected at the Unit 13 antenna. We found no evidence indicating a difference between the proportion of fish detected at each possible passage route (*i.e.*, NFB or Unit 13), or undetected in relation to release location. For the fish released at each location, about 80% passed through the NFB, 5% passed through the Unit 13 bypass, and the remaining 15% were not detected and were assumed to have passed through a turbine. While these results are consistent with previous findings, only a single replicate of juvenile steelhead were evaluated in spring 2007. Further testing is planned using both juvenile Chinook and steelhead as outlined in PGE (2006).

5. ***Post-tagging holding time appeared to influence fish passage*** — To evaluate possible effects of post-tagging holding time on juvenile steelhead passage, two groups of treatment fish were released together on 22 May; those held overnight and those released the same day as tagging. Overall, 229 treatment fish were released. Of these, 150 were tagged and held overnight, while 79 fish were tagged and held approximately 1 hour prior to release. All fish were released on the same day. Results of this evaluation suggest that steelhead held overnight prior to release may take longer to exit the forebay and may select passage routes differently than fish tagged and released the same day. For future testing, fish will be held at least overnight prior to release, unless conditions dictate otherwise (*e.g.,* emergency shut down of the plant).

6. ***Operation of the Flow Control Structure (FCS) may influence catch rates of fish***— Between the spring and fall sampling events, the Flow Control Structure (FCS) was completed at the apex of the falls, and was operated during the entire duration of the fall test period. During the first week of testing, river flow was low (~ 10K cfs), and approximately 100-150 fish were collected at the Unit 13 evaluator over a six hour period. However, once river flow increased beginning the second week in November (~ 30-40K cfs), the number of fish collected decreased substantially (*e.g.,* over a six hour period only one juvenile Chinook was collected).

7. ***Partial barriers installed along the inner trash racks may reduced hydraulic vortices along inner forebay trash racks*** — Prior to the November 15 fish releases, partial barriers were installed along the inner trash racks. While full testing of FGE

was not completed due to low fish numbers, the flow along the barriers was smooth. Further testing of FGE with barriers installed is recommended.

3.2 Unit 13 Bypass (Reach one – 13) Survival/Injury Study

A total of 114 juvenile Chinook and 249 steelhead smolts were randomly selected from the evaluator on 1 May and held for 48 hrs. Fork length of the Chinook smolts ranged from 113 mm to 173 mm, and averaged 139 mm (Table 4). Juvenile steelhead were generally larger than Chinook, ranging from 160 mm to 288 mm and averaging 220 mm.

The 48 hr direct survival rates for both species were high. Of the 114 Chinook salmon held, only three were found dead during the 48 hr holding period, which resulted in a survival estimate of 97.4%. Only one of the 249 juvenile steelhead held was found dead during the 48 hr holding period resulting in a survival estimate of 99.6%.

The only injury observed on any of the fish that had died during the 48 hr holding period was descaling; no other injuries were observed. Two of the juvenile Chinook exhibited minor descaling while the remaining fish exhibited major descaling. The single steelhead that died had minor descaling.

Overall, physical injury rates were low. Based on the NOAA criteria, less than 2% of the juvenile Chinook (n = 2/114) and 3% of the steelhead (n = 8/249) alive after 48 hrs were injured. The causal mechanism for all injuries appeared mechanical (rather than hydraulic) in nature. External scrapes and bruises were the predominant types of injuries observed, and typically occurred near the head or along the upper back and sides of the body. In several cases, single long vertical scrapes were observed down either side of the body, indicative of a mechanical “pinch”. However, it was difficult to determine if the injuries had occurred during passage through the Unit 13 bypass or if they had been inflicted prior to passage. Many of the injuries observed appeared to be healing and some cases new scale growth was present.

Descaling was quantified separately from physical injury according to the NOAA criteria. Some patchy scale loss was observed for nearly all fish examined. However, scale loss exceeded the 3% threshold set by the NOAA criteria in 43% of the juvenile Chinook and 37% of the steelhead examined. The majority of the descaling observed was classified as minor for both species, although major descaling (>40% along one side of the body) was observed in 17% of the juvenile Chinook and 8% of the steelhead (Table 4). Similar to the injuries observed, it was difficult to determine whether the observed descaling was a result of passage, or was present prior to passage.

4.0 REFERENCES

PGE 1998. Evaluation of the Downstream Migrant Bypass System T.W. Sullivan Plant, Willamette Falls, Oregon. FERC No. 2233. Progress Report for 1997. February 27, 1998.

PGE 2006. T.W. Sullivan Powerhouse Evaluation of Bypass System Fish Guidance Efficiency (FGE) and Survival Performance. December 27, 2006.

Skalski, J.R. 2000. Retrospective Analysis of Fish Guidance Efficiency Trials at the T.W. Sullivan Plant, Oregon. September 2000.

Exhibit A

TABLES

Exhibit A

Table 1.

Summary of Chinook smolts PIT-tagged and released immediately upstream of T.W. Sullivan Powerhouse to evaluate FGE, spring 2007.

TREATMENT

Release Group	Tagging Date	Release Date	Total Length (mm)			Number Released	Number Detected		Detected Outside of Test Conditions	Adjusted FGE	95% CI
			Min	Mean	Max		NFB	Unit 13			
1	29-Mar	29-Mar	108	143	198	87	52	NA	0	92%	26%
2	4-Apr	4-Apr	109	136	183	56	29	1	0	77%	35%
3	6-Apr	6-Apr	111	147	201	235	150	18	0	100%	22%
4	19-Apr	20-Apr	115	138	186	239	156	35	1	95%	20%
5	24-Apr	25-Apr	104	138	205	127	NA	95	4	85%	9%
6	26-Apr	27-Apr	110	138	180	168	98	NA	1	71%	10%
Total			*104*	*141*	*205*	*912*	*485*	*149*	*6*		

NFB CALIBRATION

Release Group	Tagging Date	Release Date	Total Length (mm)			Number Released	Number Detected	Detection Efficiency
			Min	Mean	Max			
1	29-Mar	29-Mar	120	144	200	40	26	65%
2	4-Apr	4-Apr	122	142	164	39	27	69%
3	6-Apr	6-Apr	110	147	210	161	110	68%
4	19-Apr	20-Apr	113	139	203	100	83	83%
5	NA	NA	NA	NA	NA	NA	NA	NA
6	26-Apr	27-Apr	108	137	175	182	151	83%
Total			*108*	*141*	*210*	*522*	*397*	

UNIT 13 CALIBRATION

Release Group	Tagging Date	Release Date	Total Length (mm)			Number Released	Number Detected	Detection Efficiency
			Min	Mean	Max			
1	NA	NA	NA	NA	NA	NA	NA	NA
2	4-Apr	4-Apr	122	143	180	38	32	84%
3	6-Apr	6-Apr	111	146	200	160	150	94%
4	20-Apr	20-Apr	106	137	174	70	64	91%
5	25-Apr	25-Apr	112	136	182	117	105	90%
6	NA	NA	NA	NA	NA	NA	NA	NA
Total			*106*	*141*	*200*	*385*	*351*	

Exhibit A

Table 2.

Summary of steelhead smolts PIT-tagged and released immediately upstream of T.W. Sullivan Powerhouse to evaluate FGE, spring 2007.

TREATMENT

Release Group	Tagging Date	Release Date	Total Length (mm)			Number Released	Number Detected		Detected Outside of Test Conditions	Adjusted FGE	95% CI
			Min	Mean	Max		NFB	Unit 13			
1	11-May	11-May	170	219	270	160	138	9	1	98%	17%
2	17-May	18-May	175	221	310	297	228	16	5	89%	16%
3	21-May	22-May	119	219	280	230	172	16	25	98%	17%
4	23-May	24-May	176	221	273	163	NA	85	53	85%	8%
5	24-May	25-May	182	224	276	156	88	NA	45	87%	8%
Total			*119*	*221*	*310*	*1006*	*626*	*126*	*129*		

NFB CALIBRATION

Release Group	Tagging Date	Release Date	Total Length (mm)			Number Released	Number Detected	Detection Efficiency
			Min	Mean	Max			
1	11-May	11-May	175	219	270	102	96	94%
2	18-May	18-May	180	225	292	52	52	100%
3	21-May	22-May	175	225	285	115	106	92%
4	NA	NA	NA	NA	NA	NA	NA	NA
5	24-May	25-May	175	230	275	54	50	93%
Total			*175*	*225*	*292*	*323*	*304*	

UNIT 13 CALIBRATION

Release Group	Tagging Date	Release Date	Total Length (mm)			Number Released	Number Detected	Detection Efficiency
			Min	Mean	Max			
1	11-May	11-May	163	217	270	50	49	98%
2	18-May	18-May	190	223	267	31	28	90%
3	21-May	22-May	183	220	259	57	54	95%
4	23-May	24-May	178	222	269	60	57	95%
5	NA	NA	NA	NA	NA	NA	NA	NA
Total			*163*	*220*	*270*	*198*	*188*	

Exhibit A

Table 3.

Summary of Chinook smolts PIT-tagged and released immediately upstream of T.W. Sullivan Powerhouse to evaluate FGE, Fall 2007.

TREATMENT

Release Group	Tagging Date	Release Date	Total Length (mm)			Number Released	Number Detected		Detected Outside of Test Conditions	Adjusted FGE	95% CI
			Min	Mean	Max		NFB	Unit 13			
1	6-Nov	7-Nov	119	171	197	160	124	2	0	82%	29%
2	7-Nov	8-Nov	151	178	205	185	164	4	0	99%	36%
3	14-Nov	15-Nov	118	172	199	125	88	NA	0	90%	14%
Total			*118*	*174*	*205*	*470*	*376*	*6*	*0*		

NFB CALIBRATION

Release Group	Tagging Date	Release Date	Total Length (mm)			Number Released	Number Detected	Detection Efficiency
			Min	Mean	Max			
1	7-Nov	7-Nov	115	174	197	100	96	96%
2	8-Nov	8-Nov	147	173	200	93	86	92%
3	15-Nov	15-Nov	132	177	200	110	86	78%
Total			*115*	*175*	*200*	*303*	*268*	

UNIT 13 CALIBRATION

Release Group	Tagging Date	Release Date	Total Length (mm)			Number Released	Number Detected	Detection Efficiency
			Min	Mean	Max			
1	7-Nov	7-Nov	153	173	199	50	47	94%
2	8-Nov	8-Nov	152	175	197	50	40	90%
3	NA	NA	NA	NA	NA	NA	NA	NA
Total			*152*	*174*	*199*	*100*	*87*	

Exhibit A

Table 4.

Summary of results for the 48 hour holding test at T.W. Sullivan Powerhouse (1 May - 3 May, 2007).

	Chinook	Steelhead
Number collected	114	249
Number dead (24h)	3	1
Number dead (48h)	0	0
Direct 48h survival	0.97	0.996
Numbered injuried	2	8
Number descaled	46	91
Minor	41	84
Major	5	7
Average length (mm)	139	220
Min	113	160
Max	173	288

Exhibit A

FIGURES

Exhibit A

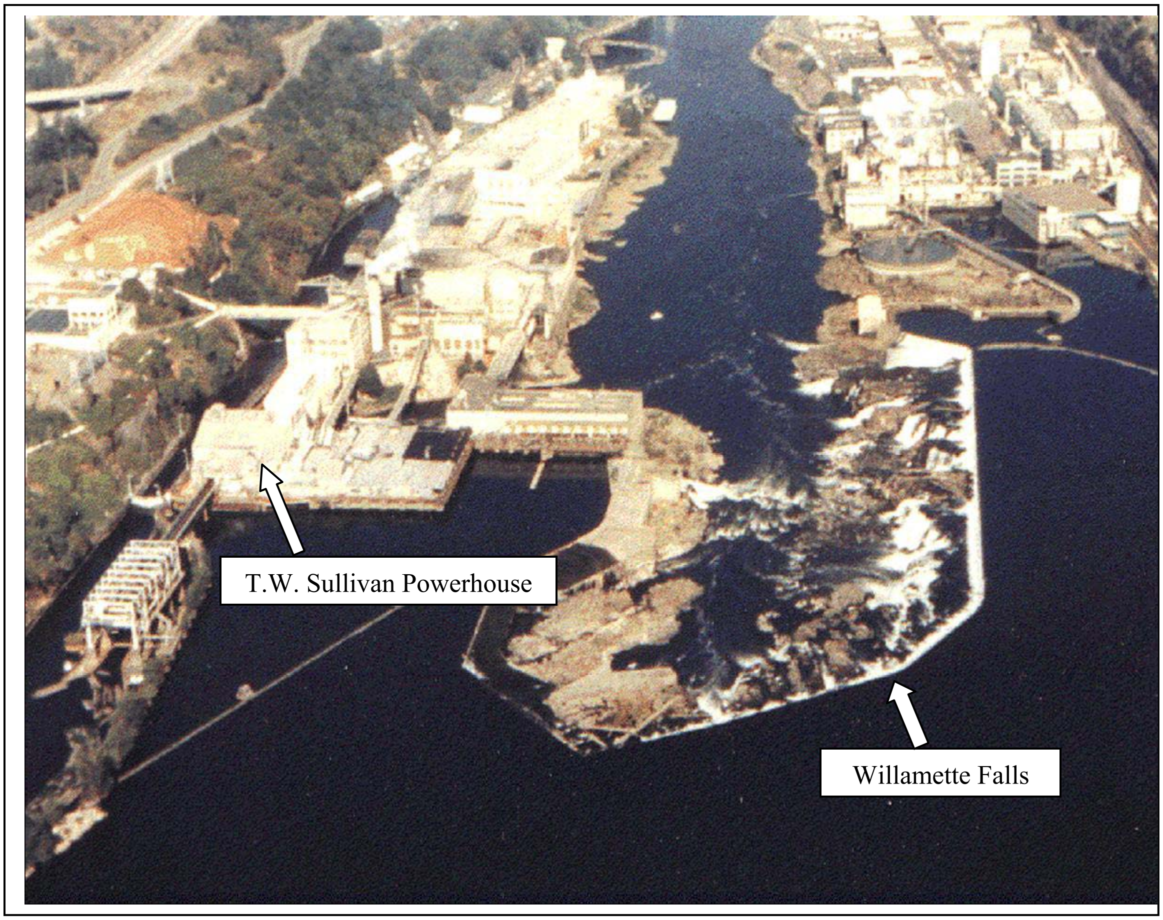

Figure 1.

Generalized layout of the Willamette Falls Project.

Exhibit A

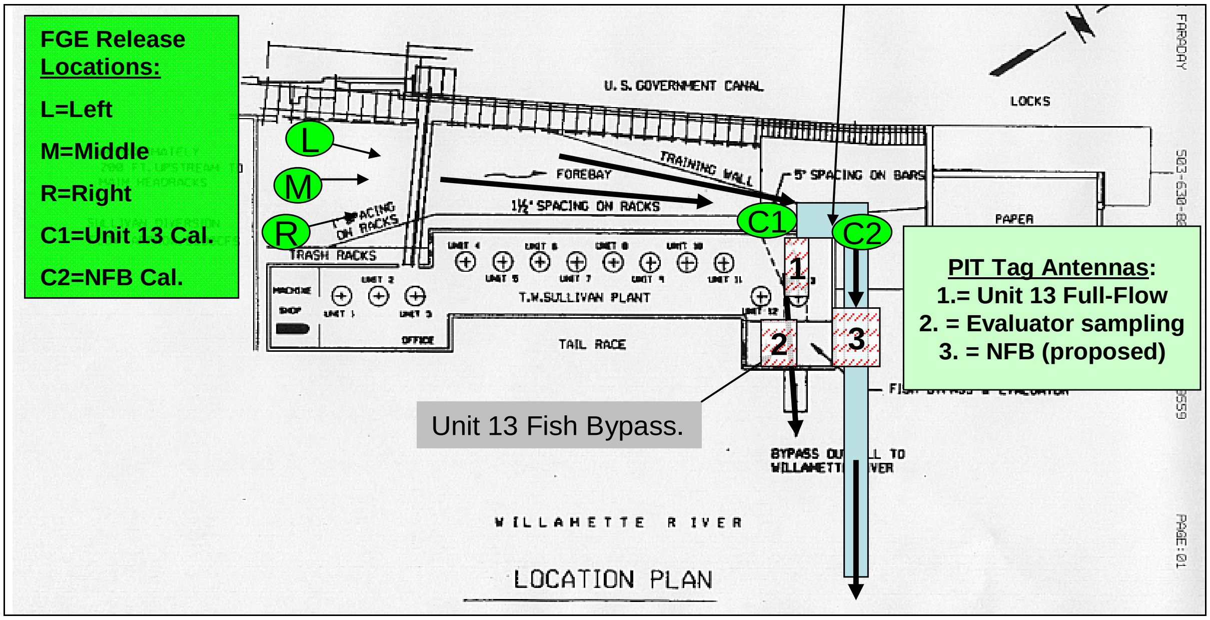

Figure 2.

T.W. Sullivan forebay and fish bypass facilities.

Exhibit A

APPENDIX A

Detailed descriptions of each FGE test conducted in spring and fall 2007

Chinook (Spring)

29 March Tests (NFB only):

The dividing wall between Units 12 and 13 failed, causing an emergency shut down of Unit 13. Consequently, all fish tagged the morning of 29 March were released that same day following the shut down of Unit 13 and just prior to the forebay dewatering. Flow through the NFB was set at approximately 400 cfs, and the forebay and tailrace elevations were 52.5 msl and 12.5 msl, respectively. All other turbine units were running, and were operating within 1% of efficiency. The hydraulic vortices in the forebay were minimal.

In total, 127 juvenile Chinook were released; 40 as calibration fish through the NFB and 87 upstream near the intake racks as treatment fish. The calibration test resulted in a detection probability that was relatively low, with only 26 (65%) of the 40 being detected. The noise reading on the antenna ranged from 1 – 2%. Fifty-two of the 87 treatment fish were detected at the NFB, which when adjusted for detection efficiency, resulted in an estimated FGE of 92% with an associated 95% confidence interval of ±26%.

4 April Tests (NFB and Unit 13 bypasses opened):

Relatively few fish were released with both the NFB and Unit 13 bypasses open. All turbines were operating within 1% of efficiency. The hydraulic vortices in the forebay were severe. Flow through the NFB was set at approximately 400 cfs, the forebay elevation was 51.5 msl, and the tailrace elevation was 9.8 msl.

Two calibration groups of approximately the same size were released. The first group was released through the NFB (n = 39) which resulted in a detection efficiency of 69%, while the second group released through the Unit 13 bypass (n = 38) resulted in a higher detection efficiency of 84%. A total of 56 treatment fish were released, 29 of which were detected at the NFB and one was detected at Unit 13 antenna. Estimated FGE was 77% with an associated 95% confidence interval of ±35%.

6 April Tests (NFB and Unit 13 bypasses opened):

In an effort to improve the hydraulic conditions in the forebay, Unit 11 was shut off, all other turbines were operated outside of efficiency, and flow through the NFB was reduced to approximately 270 cfs. These changes appeared to reduced the magnitude of the hydraulic vortices in the forebay. During this test, the forebay elevation was 52 msl, and the tailrace elevation was 9.5 msl.

Nearly equal sample sizes of fish were released at each calibration site; 161 fish were released immediately upstream of the NFB antenna and 160 upstream of the Unit 13 antenna. Detection efficiency for the NFB antenna was (68%) which was lower that the detection efficiency of the Unit 13 antenna (94%). A total of 235 treatment fish were released upstream, of which, 150 were detected at the NFB antenna and 18 were detected at the Unit 13 antenna. When adjusted for detection efficiency, the estimated FGE was 100% with an associated 95% confidence interval of ±22%.

20 April Tests (NFB and Unit 13 bypasses opened):

Similar to the test conducted on 6 April, the hydraulic vortices in the forebay were minimized by the configuration of the powerhouse and reduced flow through the NFB. During this test, Unit 10 was shut off and all other remaining units were operated within 1% of efficiency. Discharge through the NFB was set at approximately 270 cfs, and the forebay and tailrace elevations were 52.7 msl and 10.5 msl, respectively.

The detection efficiency of the NFB antenna was higher than in previous tests with 83 of the 100 calibration fish (83%) being detected. This increase in detection efficiency was largely attributed to releasing on a Friday when there is generally less extraneous noise to interfere with the antenna. Noise levels at the NFB antenna ranged from 0 – 1%. The detection efficiency of the Unit 13 antenna was also high at 91% (64/70). The treatment group comprised of 239 fish, of which 156 were detected passing through the NFB antenna and 35 were detected passing through the Unit 13 antenna. One fish was detected passing through Unit 13 on 25 April after tests conditions had changed, and was subsequently removed from the analysis and not assumed to have passed through the powerhouse. After adjusting for detection efficiency, the estimated FGE was calculated to be 95% with an associated 95% confidence interval of ±20%.

25 April Tests (Unit 13 only):

To evaluate FGE of the Unit 13 bypass operating independently, the NFB was closed. During this test, the hydraulics vortices were minimal, and the forebay and tailrace elevations were 52.4 msl and 9.4 msl, respectively. All turbines were operating and were within 1% of peak efficiency.

A group of 117 calibration fish were released immediately upstream of the Unit 13 antenna. Of these fish, 105 were detected, which resulted in a detection efficiency of 90%. A total of 127 treatment fish were initially released. However, four of these fish were detected after the test, when the NFB had been opened and the powerhouse configuration had changed. These fish were subsequently removed from the sample and were not assumed to have passed through the powerhouse. Of the remaining 123 treatment fish, 95 were detected passing through the Unit 13 bypass. The FGE estimate after adjusting for detection efficiency and removing non-test fish was 85% with an associated 95% confidence interval of ±9%.

27 April Tests (NFB only):

FGE was evaluated with only the NFB operating and with flow set at approximately 400 cfs. All turbines excluding Unit 13 were on and operating within 1% of peak efficiency. The hydraulic vortices in the forebay were present and were considered severe.

One hundred eighty-two calibration fish were released in conjunction with 168 treatment fish. The ensuing detection efficiency of 83% (151/182) resulted in a FGE estimate of 71% with an associated 95% confidence interval of ±10%. One fish was detected passing through Unit 13 on 29 April after tests conditions had changed, and was subsequently removed from the analysis and not assumed to have passed through the powerhouse.

Steelhead

11 May Tests (NFB and Unit 13 bypasses opened):

During this initial FGE test using juvenile steelhead, discharge through the NFB was set at approximately 270 cfs. Due to relatively low river flow, Unit 10 was not operating, but all other units were operating within 1% of peak efficiency. The forebay elevation was 50.8 msl and the tailrace elevation was 10.3 msl. The hydraulic vortices in the forebay were not severe.

The power line directly over the NFB antenna was removed on 23 April, the amount of ambient electronic noise detected on the NFB antenna decreased. In addition, several other sources of electrical noise were identified in the immediate area and were controlled. These measures reduced electronic noise and improved the detection efficiency of the PIT tag antenna in the NFB.

Of the 102 calibration fish released upstream of the NFB antenna 96 (94%) were detected. The Unit 13 antenna also had a high detection efficiency with 49 of 50 calibration fish detected (98%).

In effort minimize the effects of handling and holding time, treatment groups were released the same day as they were tagged. One-hundred sixty steelhead were released upstream as treatment fish after a holding period of less than 6 hours. Of these fish, 138 were detected at the NFB antenna and 9 were detected at the Unit 13 antenna. One fish remained in the forebay for eleven days before it was detected passing through the NFB on 22 May; it was removed from the FGE calculation. After adjusting for detection efficiency, the estimated FGE was calculated to be 98% with an associated 95% confidence interval of ±17%. One fish remained in the forebay for eleven days before it was detected passing through the NFB on 22 May; it was removed from the FGE calculation.

18 May Tests (NFB and Unit 13 bypasses opened):

This test was designed to evaluate whether release location influenced passage route. Conditions in the forebay were maintained as closely as possible to those tested on 11 May; all turbines except Unit 10 were operating within 1% of peak efficiency, discharge through the NFB was set at approximately 270 cfs, and the forebay and tailrace elevations were similar at 50.8 msl and 11.3 msl, respectively. The hydraulic vortices in the forebay were also minimal. After tagging, test fish were held overnight before release.

Detection efficiency of both antennas was high; all 52 fish released upstream of the NFB antenna were detected, and 28 of the 31 fish released through the Unit 13 antenna were detected (90%). Three groups of nearly equal sample sizes were released upstream as treatment fish at the Right (n = 99), Middle (n = 99), and Left (n = 99) release locations for a total of 297 fish. Overall, 228 of these fish were detected at the NFB antenna, and 16 were detected at the Unit 13 antenna. Statistically, there was no significant difference among the proportion of fish detected at each possible passage route (*i.e.*, NFB, or Unit 13) or undetected in relation to where they were released ($\chi^2 = 0.2998$, df = 4, p = 0.9898). Of the fish that passed from each release location, about 80% passed through the NFB, 5% through the Unit 13, and the remaining 15% were not detected and were assumed to have passed through a turbine.

The combined FGE estimate (after adjusting for detection efficiency) was 89% with an associated 95% confidence interval of ±16%. A total of five fish, three from the right release and one from both the middle and left release locations were detected passing the project after operations had changed. These fish were removed from the analysis, and were not assumed to be turbine passed fish.

22 May Tests (NFB and Unit 13 bypasses opened):

To evaluate possible effects of holding time on fish passage behavior, two groups of treatment fish were released together; one group of 150 fish which was held overnight and another group of 80 fish which was tagged and released approximately 1 hour after tagging; overall 230 treatment fish were released. The hydraulic conditions in the forebay were similar to those during the previous two studies; the discharge through the NFB was set at approximately 270 cfs, all but one turbine (Unit 5) was operating, and the forebay and tailrace elevations were 51.4 msl and 10 msl, respectively. Detection efficiency was high for both antennas during this test (NFB = 92% and Unit 13 = 95%).

In an attempt to collect additional fish for subsequent testing, the NFB was closed at 1450 hrs, approximately 4 hours after the first test fish were released and only 1.5 hours after the last test fish were released. Prior to the change, 172 fish were detected passing through the NFB antenna and 16 were detected passing through the Unit 13 antenna. Due to the short duration of the test, some tagged fish remained in the forebay and were detected after the project operations changed. In total, 25 fish (n = 8 NFB and n = 17 Unit 13) passed after the change in operations. If these 25 fish are removed from the sample, the estimated FGE after accounting for detection efficiency during the test period is 98% with an associated 95% confidence interval of ±17%. However, this estimate is likely conservative as it is probable that not all fish that passed during this period were detected.

There was evidence suggesting that steelhead held overnight after tagging may take longer to exit the forebay than fish tagged and released the same day. Upon further examination of the 25 fish that delayed passage until after operations had changed, all except one fish was had been held overnight prior to release. This difference may be associated with a longer recovery time and improved swimming ability, which could enable fish to orient better in flow or allow fish to seek refuge more easily.

There was also evidence to indicate that a longer recovery time may also influence passage selection. Of fish that passed the project from each group; 12% percent of the fish held overnight were detected passing through the Unit 13 bypass, whereas 4 % of those that were tagged and released the same day were detected at the Unit 13 antenna.

24 May Tests (Unit 13 only):

During this test, the NFB shut down and only the Unit 13 bypass was operating. All other turbines were on and operating within 1% of peak efficiency. The forebay elevation was 51.4 msl and the tailrace elevation was 9.3 msl. The hydraulic vortices in the forebay were present, although they appeared to be less severe than when the NFB was also operating.

A total of 60 juvenile steelhead were released as calibration fish immediately upstream of the Unit 13 antenna. Of these, 57 were detected, which resulted in a detection efficiency of 95%. Treatment fish were tagged and held overnight prior to release. Of the 163 fish released, 85 were detected by the Unit 13 antenna before the NFB was opened at 0930 hrs the following day. Fifty-three fish passed after the NFB was opened and project operations had changed (n = 51 NFB and n = 2 Unit 13). If these fish are removed from the sample, the resulting FGE estimate after adjusting for detection efficiency was calculated to be 85% with an associated 95% confidence interval of 8%. This estimate of FGE is likely conservative as it does not account for the detection probability of fish passing after the test conditions had changed, and it is probable that some of the fish that passed during this period were not detected. For instance, over 95% of the fish that passed through the NFB passed immediately (within one hour?) after it was reopened on 25 May. During that period, the detection efficiency of the antenna was determined to be 87% (see 25 May study description below). If the number of fish that passed was adjusted for detection efficiency, an estimated 59 fish likely passed through the NFB, result in an estimated FGE estimate of 88%.

25 May Tests (NFB only):

This test of FGE was conducted with the NFB operating independently. The attraction flow was set at approximately 270 cfs, and all turbine units (except Unit 13) were operating within 1% of peak efficiency. The forebay elevation was 51.2 msl and the tailrace elevation was 9.8 msl.

Noise levels were relatively high (> 3%) at the antenna when the NFB was opened on 25 May. Since a large number of fish released on 24 May passed during this period, 55 calibration fish were released to estimate detection probability. Of these fish, only 48 were detected (87%). The source of the noise was isolated and removed, and an additional 54 calibration fish were released with noise levels ranging between 0 -1%. At the lower noise levels, 50 fish were detected, improving the detection efficiency of the NFB antenna to 93%. Only fish released during this second calibration release were included to estimate detection efficiency. After the second calibration release was completed, 156 treatment fish, (which were held overnight after tagging), were released upstream at approximately 1100 hrs. Unfortunately, project operations required that the Unit 13 be opened at 1320 hrs, only a few hours later after the release. Prior to opening Unit 13, 88 fish were detected passing through the NFB. Once the Unit 13 was opened, an additional 45 fish were detected (n = 44 NFB and n = 1 Unit 13).

Similar to the test conducted on 24 May, it is difficult to derive an accurate estimate of FGE with the NFB operating independently, since a large number of fish passed after the project operations had changed. If the 45 fish that were detected subsequent to the Unit 13 was put back online were removed from the sample, the adjusted FGE estimate would be 87% with a 95% confidence interval of 8%. However, similar to other release groups where a large number of fish were detected after project operations had changed, this estimate is likely conservative.

Chinook (Fall)

7 November Tests (NFB and Unit 13 bypasses opened):

For this initial fall test using juvenile Chinook, Unit 5 was offline for repair and all other units were operating within 1% of efficiency. Flow through the NFB was set at 270 cfs, and the forebay and tailrace elevations were 51.5 msl and 7.5 msl, respectively. The hydraulic vortices in the forebay were present.

A total of 310 juvenile spring Chinook smolts were tagged and released. Of these 100 were released to calibrate the NFB antenna (detection efficiency 96%), 50 were released to calibrate the Unit 13 antennae (detection efficiency 94%), and the remaining 160 were released upstream at the middle released location as treatment fish. One hundred twenty four treatment fish were detected passing through the NFB and two were detected passing through the Unit 13. Estimated FGE was 82% with an associated 95% confidence interval of ± 29%.

8 November Tests (NFB and Unit 13 bypasses opened):

Conditions similar to those tested on 7 November were tested the following day, however in addition to Unit 5 being offline, Unit 1 was also offline for maintenance. All other units were operating within 1% of efficiency. Flow through the NFB was set at 270 cfs, and the forebay and tailrace elevations were 51.0 msl and 7.5 msl, respectively. The hydraulic vortices in the forebay were present.

Detection efficiencies at each antenna were similar to those found the previous day (7 November). Of the 93 Chinook released upstream of the NFB antenna, 92 % (n = 86) were detected. Of the 50 Chinook released upstream of the Unit 13 antenna, 90% (40) were detected. One hundred twenty four of the 160 treatment fish were detected passing through the NFB and two were detected passing through the Unit 13, resulting in an overall estimated FGE of 99% with an associated 95% confidence interval of ± 36%.

15 November Tests (NFB bypass opened):

The Unit 13 bypass was shut down after the PIT tag antennae within the Eicher did not detect the first 50 calibration fish. Unit 5 was offline; all other units were operating within 1% of efficiency. Flow through the NFB was set at 270 cfs, and the forebay and tailrace elevations were 52.0 msl and 7.75 msl, respectively. Partial barriers were installed along the inner trash racks in front of Units 2-4. The hydraulic vortices in the forebay were not present along the barriers, but did occur further downstream along the trash rack where the barriers were not present.

One hundred and ten calibration fish were released in conjunction with 125 treatment fish. The ensuing detection efficiency of 78% (86/110) resulted in a FGE estimate of 90% with an associated 95% confidence interval of ±14%.

Exhibit A

APPENDIX B

NOAA Injury Criteria

Exhibit A

Appendix B.

DESCALING CRITERIA
Revised: April 14, 1988

Sections of the Fish:

RIGHT LEFT

Sample Size: A 100 fish minimum combined sample, or no less than 50 fish per species must be used. Always report percent descaled along with the number of fish sampled.

Examination: All areas of the fish are examined for scale loss except the ventral surface from the pectoral fins to the vent (the shaded area in above figures) and scale loss is recorded as follows:

"OK" - If scale loss is 3% or less in all sections as checked.

"6" - If individual scales are lost in a scattered or diffuse pattern and greater than 3% per section but a cumulative scale loss equivalent to less than 40% of two sections, record as (L6) or (R6) as appropriate.

"6P" - If scale loss is in localized areas or patches and more than 3% per section but a cumulative scale loss equivalent to less than 40% of two sections record as (L6P) or (R6P).

"Descaled" If cumulative scale loss equals or exceeds 40% of two body sections record as (DR) or (DL).

"NOTE": Cumulative scale loss = the sum of the area of all patterns of scale loss (narrow band, patch, sectional, etc.) on one side of a fish. If regeneration of scales is obvious, then those sections with regenerating scales shall not be considered scale loss.

"7" - If the fish has an eye or a head injury record a (L7) or (R7).

"8" - If the body of the fish shows visible cuts or bruises, record as (L8) or (R8).

"9" - Mortality.

Suggested Optional Descaling Criteria - to be used at the discretion of onsite personnel to provide detailed descaling information as needed for onsite use.

"7O" - Designates folded or torn operculum.
"8B" - Designates bird marks.
"8M" - Designates mammalian predator marks.
"8P" - Designates external parasites.
"8F" - Designates external fungal infection.
"8SF"- Designates split fin. Fin must be split all the way to the base

Exhibit B

T.W. Sullivan Powerhouse Evaluation of Bypass System
Fish Guidance Efficiency (FGE), 2008

Exhibit B

ANNUAL REPORT

FTC REVIEW DRAFT

T.W. Sullivan Powerhouse
Evaluation of Bypass System
Fish Guidance Efficiency (FGE)

2008

PREPARED FOR:
Portland General Electric Company

PREPARED BY:
Normandeau Associates, Inc.
(C. M. Karchesky, M. E. Hanks, and R. D. McDonald)
Stevenson, Washington

Normandeau Associates Project No. 21313.002

December 2008

Exhibit B

This report has been prepared by:
NORMANDEAU ASSOCIATES, INC.

Project Manager – Christopher M. Karchesky, Fisheries Biologist
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This study should be cited as: Karchesky, C.M., M. E. Hanks, and R. D. McDonald. 2008. Annual Report: T.W. Sullivan Powerhouse Evaluation of Bypass System Fish Guidance Efficiency (FGE), 2008. Prepared for Portland General Electric.

Exhibit B

EXECUTIVE SUMMARY

This report summarizes the results of the second year of the post-construction evaluation to estimate fish guidance efficiency (FGE) of hatchery reared spring Chinook *Oncorhynchus tshawytscha* and steelhead *O. mykiss* smolts at the T.W. Sullivan Powerhouse. The North Fish Bypass (NFB) was recently constructed at the north end of the powerhouse, adjacent to the existing Unit 13 Bypass. The NFB was designed to increase flows through the inner forebay so that velocities increase towards the bypass and provide fish that have entered the inner forebay with an additional non-turbine passage route downstream. The NFB can work independently or in conjunction with the existing Unit 13 Bypass.

Passive integrated transponder (PIT) tags were used to evaluate FGE. PIT tag detection antennas were located in both bypasses to monitor passage of tagged fish. Run-of-the-river hatchery reared smolts were collected in the Unit 13 bypass evaluator for this evaluation. Juvenile Chinook and steelhead were collected and tagged during the spring, and only Chinook were collected and tagged during the fall. All fish were tagged with a standard 12mm SGL TX1400 PIT tag using standard methods. The detection efficiency of each PIT tag antenna was evaluated through the testing period by releasing groups of tagged fish immediately upstream of the antennas. This was done in conjunction with test fish, which were released into the forebay approximately 20 feet downstream of the main head gates.

To establish a baseline estimate of FGE for the anticipated “normal” operating conditions, only one test scenario was evaluated in 2008. Under this scenario, all test fish were released while both bypasses were operating and with all turbine units on. Flow through the NFB was set at 400 cfs.

Passage data were analyzed based on the alternative likelihood model designed to estimate FGE through a dual bypass route. This model incorporates the detection probabilities of each PIT tag antenna, the number of treatment fish released, and the number of fish detected to derive an adjusted estimate of FGE. Data regarding travel time through the inner forebay and other variables (*i.e.*, operational head, river flow, and ambient light intensity) was also obtained and included in the analysis to help determine factors that may influence FGE.

Testing in the spring began on 26 March using juvenile Chinook salmon and 24 April using steelhead. A total of 2,901 hatchery reared Chinook (1,429 treatment, 838 NFB calibration, and 634 Unit 13 calibration) and 2,342 steelhead smolts (1,038 treatment, 638 NFB calibration, and 666 Unit 13 calibration) were tagged and released to evaluate FGE. An additional 2,477 hatchery Chinook (1,238 treatment, 608 NFB calibration, and 631 Unit 13 calibration) were tagged and released in the fall.

Combined detection efficiencies were calculated based on statistically comparable release groups for each PIT tag antenna and for each species tested. These data were included in the analytical data set. For the NFB antenna, the combined detection efficiency for Chinook was 80.8% and for juvenile steelhead was 87.3%. For the Unit 13 detection antenna, the combined detection efficiency for Chinook smolts was 90.2% and for steelhead was 93.5%.

For the purpose of calculating FGE, we combined treatment groups in which paired calibration releases could be pooled for both detection antennas. This insured that only comparable data regarding detection rates were included, and that data derived using either statistically higher or lower detection efficiencies did not bias the estimate. In total, 1,832 juvenile Chinook and 755 steelhead were considered in the analytical data set for estimating FGE. Of these fish, 83.2% of the Chinook and 91.8% of the steelhead were detected at either the NFB or Unit 13 antennas. After adjusting for detection efficiency, the results of the alternative likelihood model for a dual bypass scenario indicated that FGE for juvenile Chinook was 100% (1.000, 95% CI = 9%), and for juvenile steelhead was also 100% (1.000, 95% CI = 13%).

Exhibit B

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1.0 INTRODUCTION AND BACKGROUND

The Willamette Falls Hydroelectric project (FERC No. 2233) is located on the Willamette River at river mile 26.2, approximately 5 miles south of Portland, Oregon. Willamette Falls is a naturally occurring, 40-ft-high horseshoe shaped basalt rock formation with a low concrete gravity dam along its entire crest (Figure 1). On 8 December 2005, Portland General Electric Company (PGE) was issued an Order by the Federal Energy Regulatory Commission (FERC) approving the Settlement Agreement and issuing a New License for the Willamette Falls Project. Contained in the new FERC license is "Ordering Paragraph E" which makes the conditions submitted by the National Marine Fisheries Service (NMFS) under section 18 of the Federal Power Act a requirement of the license. Among the conditions contained in the License is a stipulation that establishes downstream juvenile salmonids passage protection goals of greater than or equal to 98% survival for downstream migrating salmonids as they pass through the T.W. Sullivan powerhouse. This report is an overview and summary of the second year of testing Fish Guidance Efficiency (FGE) at the T.W. Sullivan plant with the newly constructed North Fish Bypass system (NFB) in operation.

Since the forebay of the T.W. Sullivan plant is oriented parallel with river flow, the fish bypass system at the project is designed to operate as a louver system. Fish entering the forebay are guided along the intake racks installed upstream of the turbine intakes and exit the forebay through either the newly constructed NFB or through the existing Unit 13 bypass. The purpose of the NFB is to increase flows through the forebay so that velocities increase towards the bypass and to provide an additional opportunity for non-turbine downstream passage of fish that have entered the inner forebay. The NFB is located adjacent to turbine unit 13, and was designed to work independently or in conjunction with the existing Eicher screen bypass system (Unit 13 Bypass; Figure 2). The NFB has a design flow capacity of up to 500 cfs.

During the first year of testing, large hydraulic vortices, which formed along the inner intake screens, were thought to negatively affected passage efficiency (Karchesky *et al.* 2007). Modifications to the intake racks prior to the current evaluation reduced the intensity of the vortices and improved flow conditions in the inner forebay. The objective of this post-construction evaluation of the NFB and Unit 13 fish bypasses is to further refine the estimate of FGE for hatchery reared spring Chinook *Oncorhynchus tshawytscha* and steelhead *O. mykiss* smolts with improved flow conditions in the inner forebay.

2.0 METHODS AND MATERIALS

2.1 Data Collection and Antenna Calibration

As in 2007, passive integrated transponder (PIT) tags were used to evaluate FGE of the NFB and the existing Unit 13 bypasses at the T.W. Sullivan powerhouse in 2008. A PIT tag detection antenna was constructed specifically for the NFB and was installed in 2007. The newly installed PIT tag antenna was similar to the existing antennas installed in the Unit 13 bypass downstream of the Eicher screen and just upstream of the evaluator catch tank. The NFB and Unit 13 antennas are connected to an automated monitoring system that records the unique tag identification code as individual fish pass through the antenna. This information is combined with passage time and antenna identification (*i.e.,* NFB or Unit 13), and is then uploaded to the PTAGIS online database which is operated by the Pacific States Marine Fisheries Commission (PSMFC), where data can be queried and downloaded for analysis.

As suggested by Skalski (2000), the PIT tag antennas were calibrated for detection efficiency prior to each test release. Depending on the test scenario, one or both antennas were calibrated during each test by releasing fish immediately upstream of the antenna using an induction device. Calibration fish were released in conjunction with treatment fish to insure that antenna noise was similar for both groups.

2.2 Fish Procurement and Holding

Juvenile salmonids were collected from the catch tank in the Unit 13 bypass evaluator. Juvenile Chinook and steelhead were collected and tagged during the spring, but only Chinook were collected and tagged during the fall; juvenile steelhead do not migrate downstream in the Willamette River in the fall. To increase capture rates, the evaluator was operated at night and the NFB was typically closed during periods of fish collection. A technician remained on site while the evaluator was in operation to remove debris, and to move hatchery fish designated to be tagged into a holding tank. All fish of wild origin and others not designated to be tagged were tallied and returned back into the river.

In addition, hatchery reared Chinook smolts, which were originally procured for testing survival through the modified bypass system (Karchesky *et al.* 2008), were used to calibrate PIT tag antennas during initial testing in the spring. Use of these surplus fish increased the number of run-of-the-river fish that could be allocated for treatment releases early in the migration season.

2.3 Fish Tagging and Release

All fish selected for tagging were transferred from the Unit 13 catch tank via 5 gallon bucket to the tagging site immediately adjacent to the entrance of the NFB. All fish were anesthetized in a solution of eugenol (clove oil), measured for fork length (mm), and then injected with a standard 12mm SGL TX1400 PIT tag, using methods similar to those described in PGE (2006). Each tagged fish was scanned to verify that the tag was operational, and to establish the tag code in an electronic database so that individual fish could be later identified. Once tagged, fish were immediately transferred to a series of perforated 32 gallon holding containers, and held in groups of 30 to 60 fish (depending on fish size). The holding containers were submerged in one of two 700 gallon holding ponds which were located at the calibration and treatment release sites. Each submerged container was continually supplied with ambient river water until the fish were released. Treatment fish were held overnight and typically released the following morning. Tagged fish designated to be released for antenna calibration were generally held overnight, but some groups were tagged and released on the same day due to limited fish availability.

One treatment and two calibration release sites were designated for this study as described in PGE (2006). Briefly, calibration fish were released immediately upstream of each PIT tag antenna through a water-to-water release pipe and induction system. Treatment fish were released into the forebay approximately 20 feet downstream of the main head gates through the left release port positioned approximately halfway across the inner forebay. All released treatment fish were scanned as they were released to ensure tags were retained and to record the release time of individual fish. Treatment fish were released through a four-inch diameter flex-hose reaching from the deck to just above the water surface.

2.4 Test Scenario and Data Analysis

To establish a baseline estimate of FGE for the anticipated "normal" operating conditions, and in an attempt to release a sufficient sample to achieve the desired level of statistical precision for that estimate (Skalski 2000), only one test scenario was evaluated in 2008. Under this scenario, all test fish were released while both bypasses were operating and with all turbine units on. Flow through the NFB was set at 400 cfs. Other independent variables that could not be controlled such as water temperature, operational head (*i.e.,* the difference in forebay and tailrace elevation), total river flow, and ambient light intensity (*i.e.,* sunny or cloudy) were also recorded during each release trial. Weighted regression analysis was used to assess the potential relationship of these variables on FGE.

Passage data were analyzed based on the alternative likelihood model designed to estimate FGE through a dual bypass route (PGE 2006). This model accounts for the probability of detecting a fish (detection efficiency) at both antennas. The model compares these detection probabilities to the number of treatment fish released to the number of fish detected to derive an adjusted estimate of FGE. A Chi Square test of homogeneity was used to test whether the detection efficiencies of individual calibration releases could be pooled (by species) for use in the model, or if detection efficiencies from each individual trial had to be used in the analysis.

Information on travel time was also obtained. Travel time was defined as the amount of time between when a fish was first released and when it was detected by one of the two downstream antennas. To decrease the influence of outlying data points, travel time was evaluated based on median as opposed to mean time.

3.0 RESULTS

3.1 Overview

Testing in spring 2008 began on 26 March using juvenile Chinook salmon and was followed by 10 subsequent releases (Table 1). All testing of Chinook salmon during the spring was completed by 23 April. As the number of juvenile Chinook collected at the bypass declined and the number of juvenile steelhead increased, tagging effort shifted from Chinook to steelhead. The initial FGE test using steelhead was conducted on 24 April and testing with steelhead continued through 16 May (Table 2). A total of five releases using steelhead were conducted. Testing was suspended when the number of steelhead collected in the Unit 13 evaluator decreased to a point that did not warrant further collection or testing.

A total of 2,901 hatchery reared Chinook (1,429 treatment, 838 NFB calibration, and 634 Unit 13 calibration) and 2,342 steelhead smolts (1,038 treatment, 638 NFB calibration, and 666 Unit 13 calibration) were tagged and released to evaluate FGE in the spring (Table 1). Juvenile Chinook were generally smaller than steelhead, with a fork length averaging 143 mm, and ranging from 99 mm to 208 mm (Figure 3). Steelhead averaged 219 mm and ranged from 172 to 350 mm in length.

Testing in the fall began in November, when the number of juvenile Chinook smolts collected in the evaluator catch tank began to increase following upstream hatchery releases. The initial test with juvenile Chinook in the fall occurred 6 November and was followed by two subsequent releases (Table 1). An increase in river flow on 12 November was followed by a sudden decline in the number of fish collected at the Unit 13 evaluator. This decline in fish numbers continued until it eventually reached a level that precluded sampling.

In the fall, 2,477 hatchery Chinook smolts (1,238 treatment, 608 NFB calibration, and 631 Unit 13 calibration) were tagged and released to evaluate FGE (Table 1). Juvenile Chinook in the fall were larger than in the spring, averaging 171 mm and ranging from 123 to 218 mm in length (Figure 3).

3.2 Hydraulic Conditions

In the spring, average daily river flow recorded during each release trial varied among releases and between species; daily river flow ranged from approximately 22Kcfs to nearly 44Kcfs (Figure 4). Operational head (difference between the forebay and tailrace water elevation) ranged from 39.0 to 43.2 ft (Table 2). Water temperatures recorded during the spring evaluation period gradually increased from 6.7^{o} C to 14.4^{o} C.

In the fall, average daily river flow recorded during each release trial ranged from approximately 24Kcfs on 6 November to nearly 60Kcfs on 13 November (Figure 5). Operational head recorded during each released ranged from 39.0 to 43.0 ft (Table 2). Water temperatures recorded during each release remained consistent between 12 and 13^{o} C.

3.3 PIT Tag Reader Efficiency

Detection efficiencies varied between PIT tag antennas (*e.g*., NFB and Unit 13) and between fish species similar to those reported in 2007 (Table 1; Karchesky *et al.* 2007). In general, detection efficiencies were higher for fish passing through the Unit 13 bypass when compared to those passing through the NFB. Also, detection efficiencies were typically higher for juvenile steelhead than for Chinook smolts. However, variation in detection efficiency did occur among individual calibration releases at each antenna for both species. This variation did result in some trials not being statistically pooled to calculate the combined detection efficiency to be used in the alternative likelihood model.

The initial evaluation using the Chi Square test of homogeneity found a significant difference ($p < 0.05$) in the proportion of calibration fish detected at both the NFB and Unit 13 antennas for Chinook and at the NFB antenna for steelhead. Subsequent pairwise tests indicated that this variation was largely the result of a few calibration trials with statistically higher or lower detection efficiencies. In most cases, the reason for this variation was associated with the level electrical impedance or “noise” occurring at the antenna on the day of the release. To avoid biasing the combined detection efficiency calculated for the alternative likelihood model, calibration trials with statically higher or lower detection efficiencies were not pooled. When these few trials were excluded, the Chi-Square analysis indicated that the remaining calibration data could be pooled ($p > 0.05$) for each fish species and corresponding detection antenna.

Of the 13 NFB calibration trials of juvenile Chinook, two were not pooled due to statically higher (23 April) or lower (26 March) detection efficiencies when compared to the remaining trials (Table 1). Pooling of the remaining 11 calibration trials resulted in a combined detection efficiency for Chinook passing through the NFB of 80.8% (Table 3). Only one calibration release of steelhead through the NFB (16 May) was excluded due to unusually high antenna noise and low discrete detection efficiency. When the remaining four trials were pooled, the combined detection efficiency for steelhead passing through the NFB antenna was 87.3%.

For the Unit 13 antenna, the three initial calibration releases using Chinook smolts in the spring were found to have significantly lower detection efficiencies (< 77%), and were not pooled. This was in part attributed to antenna tuning problems, but may have also been influenced by the use of surplus hatchery fish from testing survival of the modified fish bypass system (Karchesky *et al.* 2008). All other Unit 13 calibration trials in the spring were pooled. Similar detection efficiencies were recorded in the fall at the Unit 13 antenna for juvenile Chinook, and all except one (13 November) were pooled with those recorded in the spring. The combined detection efficiency for Chinook smolts passing through the Unit 13 antenna was 90.2% (Table 3). All the calibration trials for steelhead passing through the Unit 13 antenna were pooled, resulting in a combined detection efficiency of 93.5%.

3.4 Fish Guidance Efficiency

Similar to the observations made in 2007 (Karchesky *et al*. 2007), the majority of the treatment fish released in 2008 passed through the NFB rather than the Unit 13 bypass. In the spring, approximately 91% of the juvenile Chinook and 98% of the steelhead passed through the NFB. In the fall, all except four of the 1,073 juvenile Chinook (0.4%) that were detected passed through the NFB.

For the purpose of calculating FGE, we only combined treatment groups in which paired calibration releases could be pooled for both detection antennas. This insured that only comparable detection data were included, and that data that were derived using either statistically higher or lower detection efficiencies did not bias the estimate. In total, 8 of the 13 treatment releases were pooled for Chinook smolts for a combined release group of 1,832 fish (Table 3). Of the 5 treatment releases using juvenile steelhead, four were pooled, resulting in a combined release group of 755 fish.

Of the 1,832 Chinook released in the forebay, 83.2% (n=1,524) were detected at either the NFB or Unit 13 antennas. Ninety-two percent of the 755 steelhead released in the forebay were detected at the downstream antennas.

Results of the alternative likelihood model for a dual bypass scenario indicated that FGE was high for both Chinook and steelhead smolts under the conditions tested (both bypasses open and all turbine units operating (Table 3). Estimated FGE for Chinook smolts using passage data collected in the spring and fall was 100% (1.000, 95% CI = 9%), and for juvenile steelhead was 100% (1.000, 95% CI = 13%) after being adjusted for antenna detection efficiency.

3.5 Effects of Other Independent Variables on FGE

Using FGE estimates generated from each paired calibration-treatment release, we evaluated the influence of operational head, total river flow, water temperature, and light intensity recorded at the time of release on FGE (Table 2). Since our analysis evaluated each release trial and associated calibration data independently, we were able to include all release trials into the analysis. Consequently, we used 13 FGE estimates for Chinook and five FGE estimates for steelhead. For both species, the regression analysis found no significant relationship with any of the tested variables ($P > 0.05$) and FGE (Table 4).

3.6 Travel Time

Overall, median travel time from initial release to first detection was similar between species; median travel for Chinook smolts was 2.2 minutes and for juvenile steelhead was 1.3 minutes (Table 5). A comparison of median travel time recorded in the spring between passage routes found that for both species, there was little difference between fish passing through the NFB and fish passing through the Unit 13 bypass. Median travel time for Chinook smolts detected at the NFB antenna was 1.1 minutes and at the Unit 13 bypass was 1.3 minutes; for juvenile steelhead median travel time was 1.3 minutes at the NFB and 1.7 minutes at the Unit 13 bypass.

In the fall, median travel time for juvenile Chinook was slightly higher than what was observed in the spring. Median travel time for Chinook smolts passing through the NFB was 2.4 minutes and through the Unit 13 bypass was 2.3 minutes.

4.0 DISCUSSION

Results of the 2008 evaluation indicate that estimated FGE was high (100% after being adjusted for detection antenna detection efficiency) for juvenile salmonids passing through the T.W Sullivan powerhouse forebay under the hydraulic conditions tested. Only one test scenario, which was thought to represent the anticipated normal operating conditions for the powerhouse and fish bypasses, was evaluated in the spring and fall. Under this scenario, all test fish were released while both bypasses were operating and with all turbine units on. Flow through the NFB was set at 400 cfs. Under similar operating conditions in 2007, estimated FGE for Chinook was 77% (Karchesky *et al*. 2007). This improvement in FGE suggests that changes made to the inner forebay that reduced the hydraulic vortices observed in 2007, improved fish guidance conditions.

Other possible bypass configurations were not tested in 2008 in an attempt to release enough fish under the "normal" operating condition to achieve the desired level of precision (± 2.5%) surrounding the FGE estimates (Skalski 2006). However, despite intensive collection efforts and combining data collected in the spring and fall for juvenile Chinook, we were only able to tag and release about half of the number of Chinook estimated to meet the desired level of statistical precision (PGE 2006). Fewer juvenile steelhead were available for tagging than Chinook resulting in a less precise estimate of FGE than derived for Chinook. Continued testing of the normal bypass configuration using both species is planned for 2009. These data may be combined with the 2008 data to further refine the point estimate for FGE and improve precision.

While additional testing to increase sample sizes may improve the precision of the FGE estimates based on the dual bypass model (Skalski 2006), improved precision (particularly for steelhead estimates) may also be achieved by an evaluation of the existing data based on the single bypass scenario. Less than 2% of the steelhead released during the spring passed through the Unit 13 bypass. While these fish have very little influence on the point estimate, the use of the dual bypass model inherently reduces statistical precision. When the single bypass model was used to estimate FGE for steelhead, the point estimate remained at 100%, but the estimated 95% confidence interval decreased from ± 13% to ± 4%. Further evaluation of the data is needed to determine whether the single bypass model is applicable for estimating steelhead FGE given the low proportion of fish that use the Unit 13 bypass. However, if it is determined that the single-bypass model is appropriate, this model will provide a more precise estimate compared to the dual-bypass model.

A difference in the proportion of Chinook smolts utilizing the Unit 13 bypass was observed between the spring and fall releases. In the spring, approximately 10% of the Chinook smolts that passed the powerhouse, passed through the Unit 13 bypass, whereas in the fall less than 1% passed through the Unit 13 bypass. A similar trend was also observed between spring and fall releases of Chinook in 2007 (Karchesky *et al.* 2007). The reason for this difference is unclear, but may be size related. Chinook smolts tagged in the fall were on average 40 mm longer than Chinook released in the spring. It is possible that these larger fish were stronger swimmers and had a better ability to negotiate the flows through the inner forebay and select a particular passage route. Since very few Chinook smolts passed through the Unit 13 bypass in the fall (0.4%), when these data were evaluated using the alternative likelihood model for a single bypass scenario, the estimated FGE for juvenile Chinook in the fall was 100% with an estimated 95% CI of ± 4%.

Despite attempts to isolate or remove sources of electrical noise, PIT tag reader efficiency was variable in 2008, which precluded some releases from being included in the analytical sample. While extraneous electrical noise appeared to be the primary factor influencing detection efficiency, initial calibration releases of Chinook in the spring, may have also been attributed to the use of surplus hatchery fish held over from the HI-Z balloon tag study (conducted 3 March through 14 March, 2008; Karchesky *et al.* 2008). These fish were tagged and released for calibration in an attempt to increase the number of run-of-the-river fish that could be allocated as treatment fish early in the migration season. However, these surplus fish had been held for several weeks in 700 gallon circular tanks that were continuously supplied with ambient river water. While these fish appeared to be in good physical health, they were not conditioned to a flowing environment, and may have behaved differently than actively migrating fish captured in the Unit 13 Bypass. Since fish orientation strongly influences the probability of detection by a PIT tag reader (Zydlewski *et al*. 2006), it is possible that poor swim performance immediately after exiting the release pipe contributed to the low detection efficiency. The relatively close proximity of the Unit 13 antenna to the release pipe compared to the NFB antenna may also explain why the lower detection efficiencies were more pronounced at the Unit 13 antenna. While these results are not conclusive, we recommend caution be used during future calibration releases using fish obtained directly from the hatchery. Further, we suggest that if the need to use fish that are not actively migrating arises, then the influence of these fish on detection efficiency should be evaluated.

The current estimates of FGE and estimated confidence intervals are conservative. Because collecting and releasing the necessary number of run-of-the-river fish required to achieve the desired level of precision in one release group is impossible, it is necessary to release multiple treatment and corresponding calibration groups for a particular operating condition. Individual release groups are then combined to populate the alternative likelihood model. However, since the number of treatment fish detected during a particular release trial is directly related to the corresponding detection efficiency of each antenna during that release, those calibration estimates that were found to be statically higher or lower than the estimated combined detection efficiency were not pooled to insure that only comparable detection data were included. Thus, for the purpose of calculating FGE, we only combined treatment groups in which paired calibration releases could be pooled for both detection antennas.

We did not find a significant relationship between other environmental factors and FGE under the project configuration and hydraulic conditions tested. These results are inconsistent with those reported prior to the construction of the NFB and modifications to the inner forebay and existing Unit 13 bypass (Skalski 2000). These earlier findings which incorporated FGE estimates collected over a three year period (1996 to 1999), reported a significant ($P < 0.10$)

positive relationship between operational head and fish passage success. While this comparison suggest that modifications to the inner forebay and construction of the NFB may have lessened the effects of other environmental factors on FGE, the possible influence of these variables should be consider during future testing that involves changes in project operations or hydraulic conditions (*i.e.,* lower forebay elevation).

Median travel time through the inner forebay following release was consistent between fish species (approximately 1 to 2 minute) and only varied slightly between fish passing through the NFB and Unit 13 bypasses. The most notable difference in median travel time between species and test period was the difference in maximum travel times through the inner forebay. Juvenile Chinook in the spring passed relatively quickly; with all fish passing in less than 10 minutes. Although most of the steelhead released in the spring also passed within 10 minutes, a small component of the tagged fish (approximately 2%) took over 60 minutes to pass following release. A similar observation was made for juvenile Chinook released in the fall. While the majority of the Chinook in the fall also passed in under 10 minutes, the proportion of tagged fish which took longer than 10 minutes to pass through the inner forebay increased. Approximately 2% of the Chinook released in the fall passed after 10 minutes, with 3 fish passing in over 60 minutes. The reason for this difference may be attributed to the larger body size of the Chinook released in the fall, and their increased ability to swim against the current in the inner forebay. A similar pattern was reported by Beeman and Maule (2001) when comparing residency times of juvenile Chinook and larger steelhead passing through a gatewell and fish collection channel at McNary Dam.

Results of the second year of testing at the T.W. Sullivan powerhouse indicate that FGE for both juvenile Chinook and steelhead is high under the hydraulic conditions tested. Although the desired sample size and associated goals for statistical precision around the FGE estimate were not met, a marked improvement in FGE from what was estimated under more turbulent forebay conditions in 2007 (Karchesky *et al.* 2007) and prior to the construction of the NFB (Skalski 2000) was observed. These findings provide a strong indication that recent structural modifications to the inner forebay have improved fish guidance conditions and reduced the amount of turbine passage at the powerhouse. Reduced turbine passage, when combined with the low estimates of direct mortality obtained during testing of the NFB and Unit 13 Bypass in the spring of 2008 (Karchesky *et al.* 2008), would suggest that overall survival of fish passing the T. W. Sullivan powerhouse is high. Additional testing of FGE under the "normal" operating condition is planned for 2009.

5.0 REFERENCES

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Exhibit B

TABLES

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Table 1.

Summary of Chinook and steelhead smolts PIT-tagged and released immediately upstream of the T.W. Sullivan Powerhouse to evaluate FGE, spring and fall 2008. (Release groups shaded in grey represent the analytical data set; the combined data are presented in Table 3).

CHINOOK

Release Group	Tagging Date	Release Date	Species	NFB Calibration Released	NFB Calibration Detected	NFB Calibration %	Unit 13 Calibration Released	Unit 13 Calibration Detected	Unit 13 Calibration %	Treatment Released	Treatment NFB	Treatment Unit 13
1	25-Mar	26-Mar	Chinook	119	83	69.7[a]	60	41	68.3[a]	279	173	21
2	26-Mar	27-Mar	Chinook	157	117	74.5	60	44	73.3[a]	172	114	7
3	1-Apr	2-Apr	Chinook	101	74	73.3	60	46	76.7[a]	60	34	3
4	2-Apr	3-Apr	Chinook	60	44	73.3	60	52	86.7	122	88	4
5	3-Apr	4-Apr	Chinook	80	60	75.0	60	57	95.0	83	56	5
6	8-Apr	9-Apr	Chinook	60	49	81.7	59	55	93.2	119	71	9
7	9-Apr	10-Apr	Chinook	53	42	79.2	57	51	89.5	79	55	4
8	10-Apr	11-Apr	Chinook	49	41	83.7	56	53	94.6	166	116	14
9	16-Apr	17-Apr	Chinook	99	85	85.9	96	80	83.3	221	166	24
10	22-Apr	23-Apr	Chinook	60	56	93.3[a]	66	62	93.9	128	81	10
11	5-Nov	6-Nov	Chinook	194	167	86.1	196	178	90.8	435	392	0
12	6-Nov	7-Nov	Chinook	315	264	83.8	336	301	89.6	607	516	4
13	12-Nov	13-Nov	Chinook	99	81	81.8	99	28	28.3[a]	196	161	0

STEELHEAD

Release Group	Tagging Date	Release Date	Species	NFB Calibration Released	NFB Calibration Detected	NFB Calibration %	Unit 13 Calibration Released	Unit 13 Calibration Detected	Unit 13 Calibration %	Treatment Released	Treatment NFB	Treatment Unit 13
1	24-Apr	24-Apr	Steelhead	104	88	84.6	103	98	95.1	196	177	2
2	29-Apr	30-Apr	Steelhead	114	100	87.7	119	110	92.4	173	155	1
3	30-Apr	1-May	Steelhead	117	103	88.0	118	114	96.6	152	139	2
4	8-May	9-May	Steelhead	146	129	88.4	147	135	91.8	234	212	5
5	15-May	16-May	Steelhead	157	120	76.4[a]	179	166	92.7	283	229	5

[a] Detection efficiency was not pooled due to statistically ($P < 0.05$) higher or lower detection efficiencies.

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Table 2.

Summary of conditions recorded during each treatment released at the T.W. Sullivan Powerhouse, spring and fall 2008.

Release date	Species	Water Temp C	River flow (Kcfs)	Trailrace elevation (MSL)	Forebay elevation (MSL)	Operational head (ft)	NFB flow (cfs)	Unit 13 flow (cfs)	Weather Code[a]
3/26/2008	Chinook	6.7	41.3	11.8	54.1	42.3	400	40	3
3/27/2008	Chinook	6.7	43.9	11.5	52.5	41.0	400	40	2
4/2/2008	Chinook	7.0	26.9	10.0	52.0	42.0	400	40	2
4/3/2008	Chinook	7.2	26.3	9.7	52.9	43.2	400	40	2
4/4/2008	Chinook	7.4	25.9	9.6	52.3	42.7	400	40	3
4/9/2008	Chinook	10.0	30.6	10.5	52.0	41.5	400	40	3
4/10/2008	Chinook	10.0	30.7	10.5	52.3	41.8	400	30	3
4/11/2008	Chinook	10.0	30.9	10.5	52.5	42.0	400	40	1
4/17/2008	Chinook	10.8	23.7	9.8	51.5	41.8	400	40	3
4/18/2008	Chinook	10.6	22.1	9.0	51.0	42.0	400	30	3
4/23/2008	Chinook	9.7	22.4	10.2	52.0	41.8	400	30	3
11/6/08	Chinook	12.2	23.7	9.5	52.0	42.5	400	40	3
11/7/08	Chinook	12.2	29.3	9.5	52.5	43.0	400	40	3
11/13/08	Chinook	13.0	59.0	15.0	54.0	39.0	400	40	3
4/24/2008	Steelhead	10.0	27.0	10.5	51.4	40.9	400	30	3
4/30/2008	Steelhead	12.2	32.4	10.3	51.8	41.6	400	30	2
5/1/2008	Steelhead	11.9	30.5	10.5	51.8	41.3	400	30	2
5/9/2008	Steelhead	12.8	33.8	12.5	51.8	39.3	400	30	1
5/16/2008	Steelhead	14.4	38.0	12.8	52.2	39.4	400	30	1

[a] Weather code: 1 sunny; 2 partly cloudy; and 3 cloudy.

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Table 3.

Combined data summary for each calibration and treatment release and associated FGE estimates for juvenile salmonids released at the T.W. Sullivan Powerhouse, spring and fall 2008.

	NFB CALIBRATION				UNIT 13 CALIBRATION				TREATMENT			
Species	**Released**	**Detected**	**NotDet**	**%**	**Released**	**Detected**	**NotDet**	**%**	**Released**	**NFB**	**U13**	**%**
Chinook	1,267	1,024	243	80.8	986	889	97	90.2	1,832	1,460	64	83.2
Steelhead	481	420	61	87.3	666	623	43	93.5	755	683	10	91.8

	Combined FGE Calculation[a]	
Species	**FGE**	**95% CI**
Chinook	**100%**	**9%**
Steelhead	**100%**	**13%**

[a] Combined FGE calculation based on the results of the alternative likelihood model and adjusted for detection efficiency at each antenna.

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Table 4.

Summary of weighted regression results of FGE for Chinook and steelhead against independent environmental variables recorded during release, spring and fall 2008.

	Chinook			Steelhead		
Variables	R^2	F-value	P-value	R^2	F-value	P-value
Operational head	0.008	0.09	0.7749	0.003	0.01	0.9292
Total river flow	0.087	1.05	0.3275	0.0304	0.09	0.7791
Water temperature	0.030	0.34	0.5713	0.0161	0.05	0.8391
Light intensity	0.007	0.07	0.7926	0.1071	0.36	0.5908

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Table 5.

Summary of travel times[a] for juvenile Chinook and steelhead released at the T.W. Sullivan Powerhouse, 2008. Times are shown in minutes.

Passage	Chinook						Steelhead					
Location	n	Min	Q2	Median	Q3	Max	n	Min	Q2	Median	Q3	Max
NFB	1,216	0.9	1.1	2.2	2.5	102.6	911	0.9	1.2	1.3	1.7	5146.4
Unit 13	66	1	1.2	1.4	2.0	5.1	15	1.1	1.4	1.7	16.6	4954.5
Combined	1282	0.9	1.1	2.2	2.5	102.6	926	0.9	1.2	1.3	1.7	5156.4

[a] Travel time defined as the amount of time between when a fish was first released at the head of the inner forebay and when it was detected by one of the two downstream antennas.

Table 6.

Summary of travel times for juvenile Chinook released in the spring compared to Chinook released in the fall at the T.W. Sullivan Powerhouse, 2008. Times are shown in minutes.

Passage	Chinook (spring)						Chinook (fall)					
Location	n	Min	Q2	Median	Q3	Max	n	Min	Q2	Median	Q3	Max
NFB	540	0.9	1.1	1.1	1.2	6.8	676	2.1	2.3	2.4	3.1	102.6
Unit 13	62	1.0	1.1	1.3	1.8	5.1	4	23	2.4	2.4	2.7	2.8
Combined	602	0.9	1.1	1.1	1.2	6.8	680	2.1	2.3	2.4	3.1	102.6

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FIGURES

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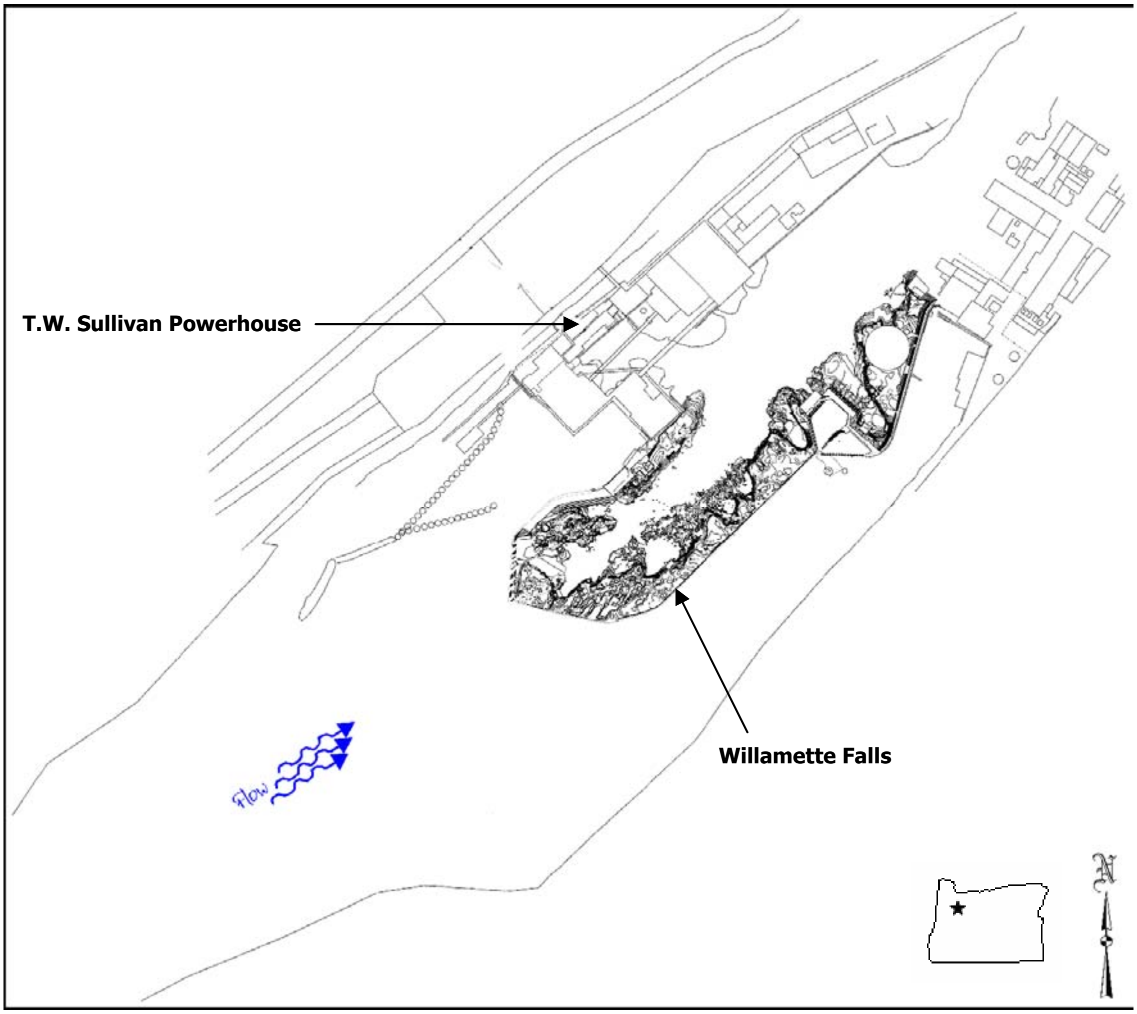

Figure 1.

Generalized layout of the Willamette Falls Project.

Exhibit B

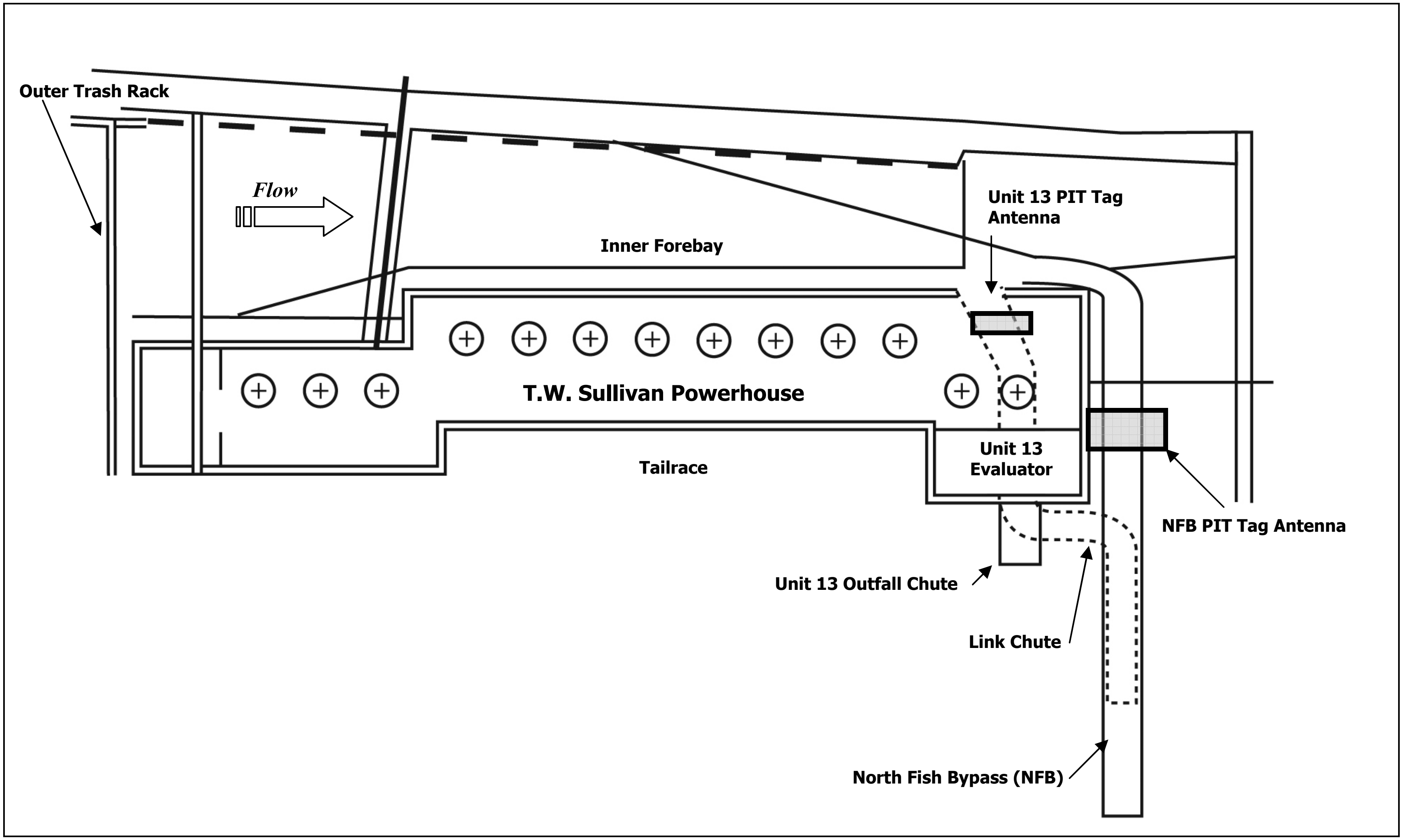

Figure 2.

T.W. Sullivan forebay and fish bypass facilities.

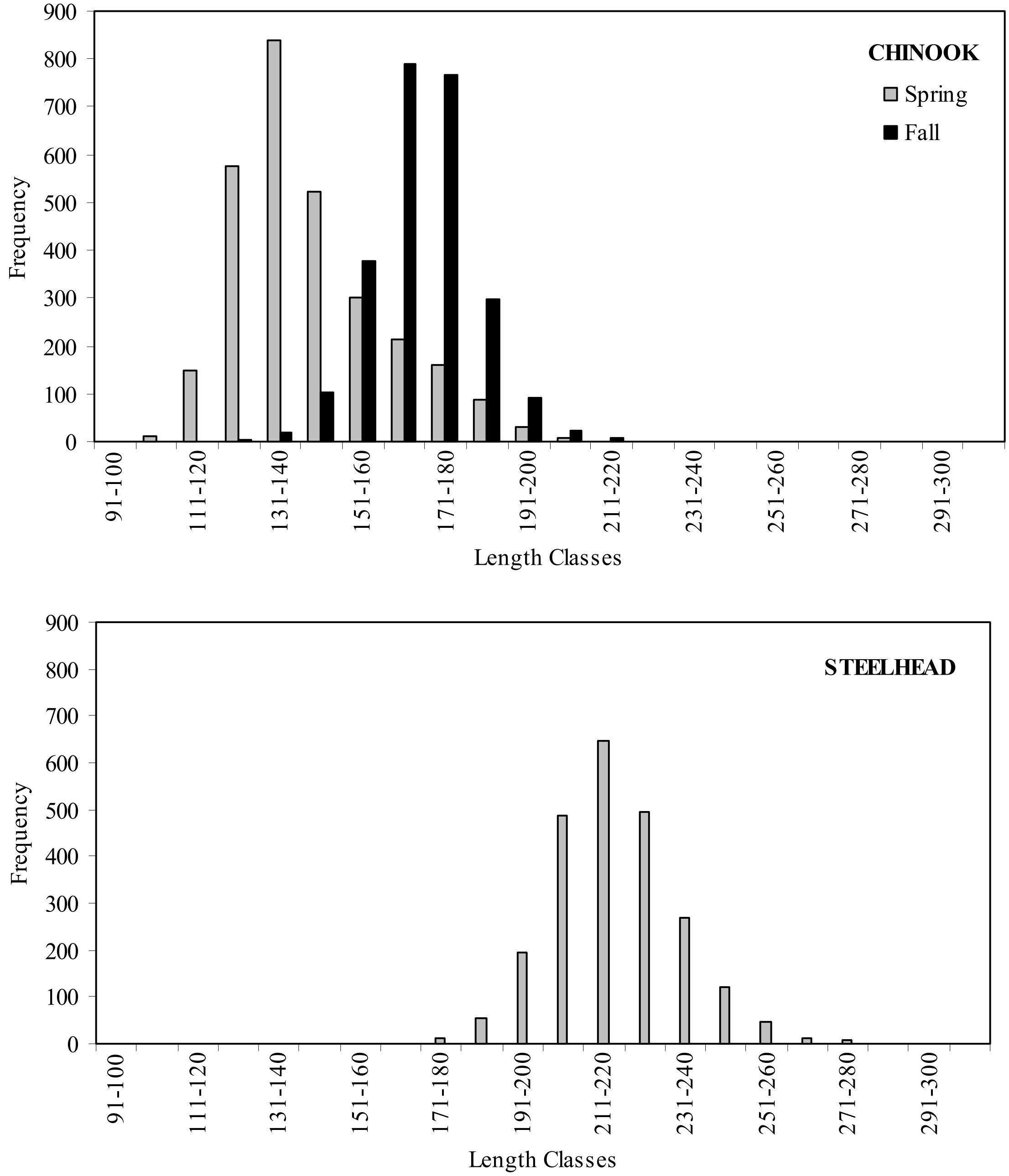

Figure 3.

Length frequency distribution of juvenile Chinook and steelhead tag and release at the T.W. Sullivan powerhouse to estimate FGE, spring and fall 2008.

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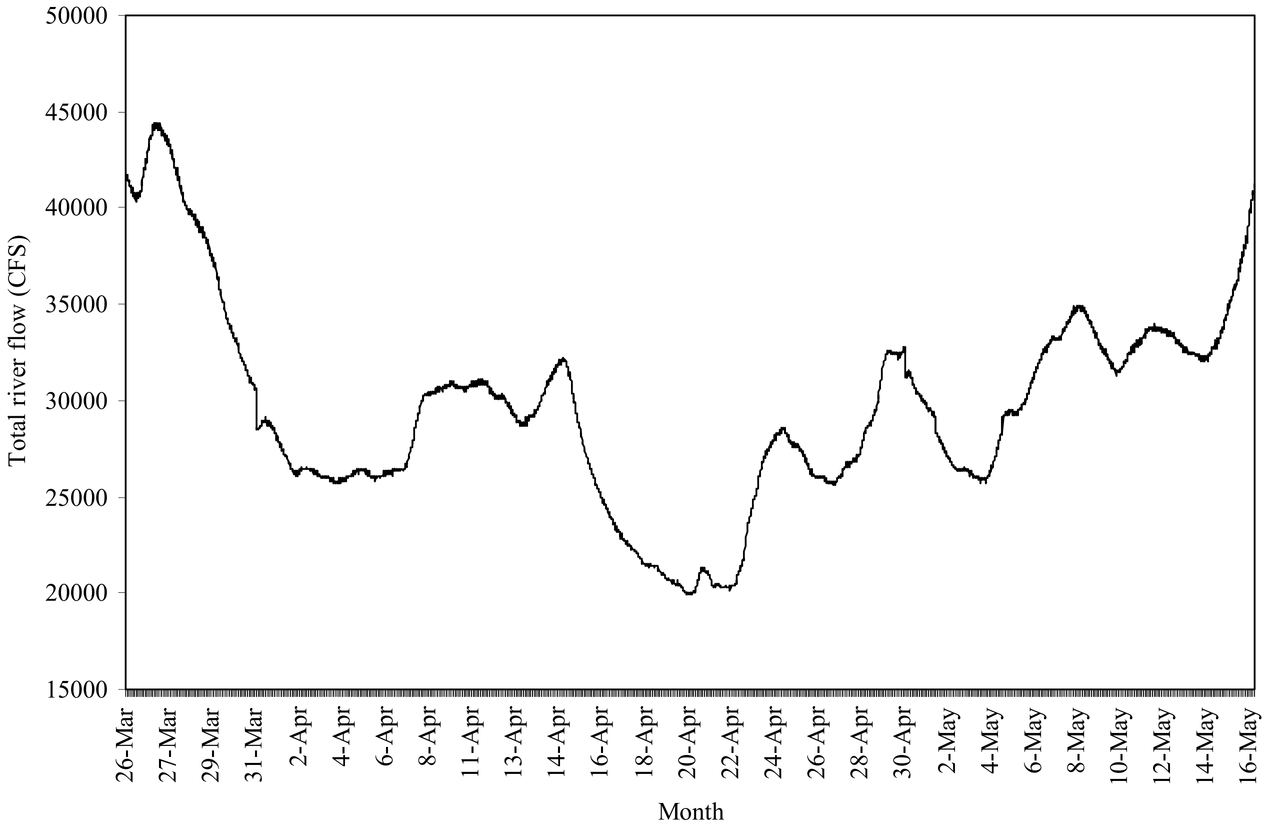

Figure 4.

Average daily river flow recorded at the USGS gauging station located upstream of Willamette Falls and adjusted for accretion recorded during the FGE evaluation period, spring 2008.

Exhibit B

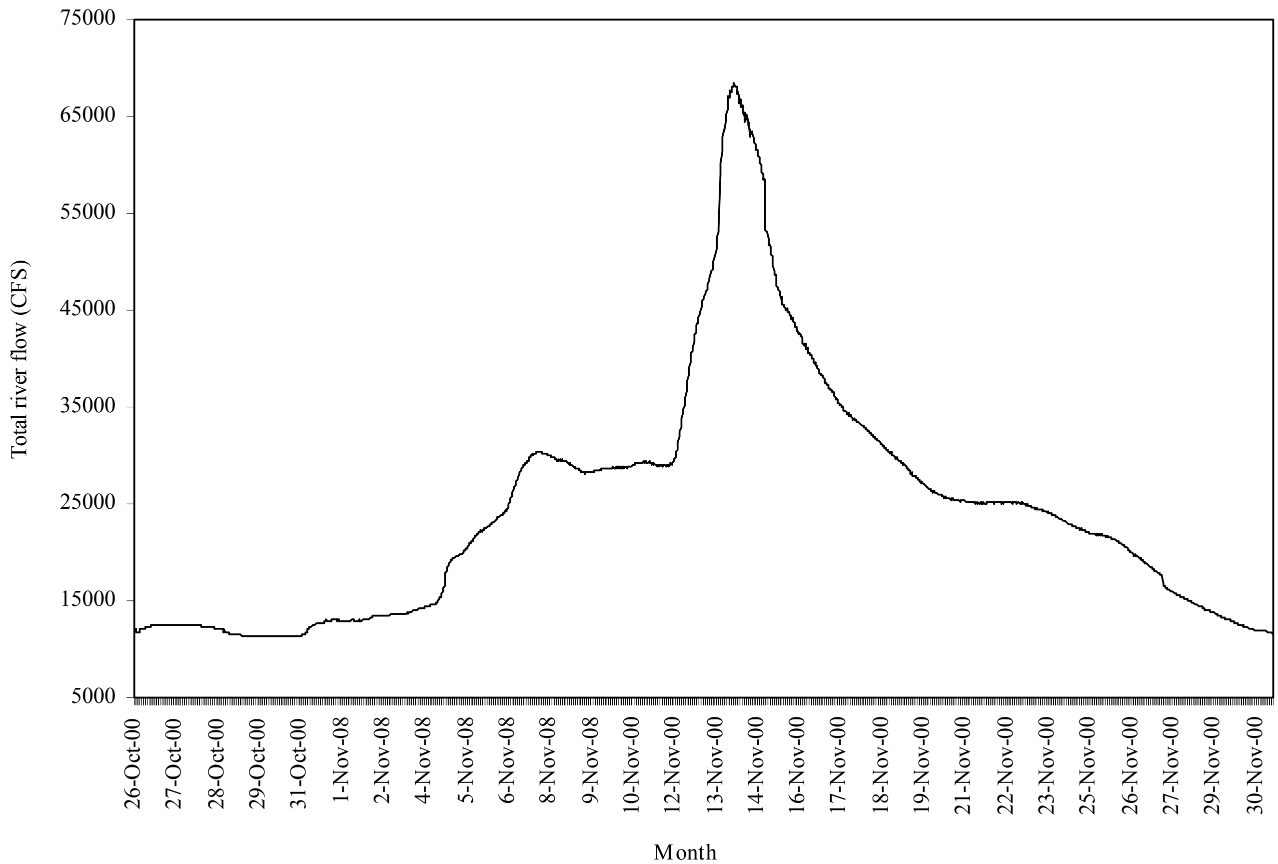

Figure 5.

Average daily river flow recorded at the USGS gauging station located upstream of Willamette Falls and adjusted for accretion recorded during the FGE evaluation period, fall 2008.

Exhibit C

T.W. Sullivan Powerhouse Evaluation of Bypass System

Fish Guidance Efficiency (FGE), 2009

Exhibit C

ANNUAL REPORT

FTC REVIEW DRAFT

T.W. Sullivan Powerhouse
Evaluation of Bypass System
Fish Guidance Efficiency (FGE)

2009

PREPARED FOR:
Portland General Electric Company

PREPARED BY:
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Normandeau Associates Project No. 21616.002

October 2009

Exhibit C

This report has been prepared by:
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This study should be cited as: Karchesky, C.M., and M. E. Hanks. 2009. Annual Report: T.W. Sullivan Powerhouse Evaluation of Bypass System Fish Guidance Efficiency (FGE), 2009. Prepared for Portland General Electric.

EXECUTIVE SUMMARY

This report summarizes the results of the third year of the post-construction evaluation to estimate fish guidance efficiency (FGE) of hatchery reared spring Chinook *Oncorhynchus tshawytscha* and steelhead *O. mykiss* smolts at the T.W. Sullivan Powerhouse. In order to continue to estimate FGE for the anticipated "normal" operating conditions, only one test scenario was evaluated in spring 2009. Under this scenario, all test fish were released while both the Unit 13 bypass and the NFB were operating and with all turbine units on. Flow through the NFB was set at 400 cfs. Data collected during 2009 was combined with data collected in 2008 to establish an overall estimate of FGE which will be used to calculate overall Project performance.

As in 2007 and 2008, passive integrated transponder (PIT) tags were used to evaluate FGE. PIT tag detection antennas were located in both bypasses to monitor passage of tagged fish. Hatchery reared smolts were collected in the Unit 13 bypass evaluator for this evaluation. Juvenile Chinook and steelhead were collected and tagged during the spring. Only Chinook were collected and tagged during the fall. All fish were tagged with a standard 12 mm SGL TX1400 PIT tag using standard methods. The detection efficiency of each PIT tag antenna was evaluated throughout the testing period by releasing groups of tagged fish immediately upstream of the antennas. These calibration releases were conducted in conjunction with releases of test fish, which were released into the forebay approximately 20 feet downstream of the main head gates.

Testing in spring 2009 began on 20 March using juvenile Chinook salmon and 24 April using steelhead. A total of 6,101 hatchery reared Chinook (3,391 treatment, 1,466 NFB calibration, and 1,244 Unit 13 calibration) and 2,004 steelhead smolts (1,033 treatment, 736 NFB calibration, and 235 Unit 13 calibration) were tagged and released to evaluate FGE.

While most of the release trials were tested under normal operating conditions, unplanned operational changes at the powerhouse and low flow resulted in some of the groups being released under conditions which differed from the "normal" test scenario. Consequently, 5,312 juvenile Chinook and 1,424 steelhead were released under normal operating conditions and subsequently combined with 2008 data to estimate overall powerhouse performance. One release trial of juvenile Chinook and two release trials of steelhead were released under atypical operating conditions and were not included in the analytical sample.

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1.0 INTRODUCTION AND BACKGROUND

The Willamette Falls Hydroelectric project (FERC No. 2233) is located on the Willamette River at river mile 26.2, approximately 5 miles south of Portland, Oregon. Willamette Falls is a naturally occurring, 40-ft-high horseshoe shaped basalt rock formation with a low concrete gravity dam along its entire crest (Figure 1).

On 8 December 2005, Portland General Electric Company (PGE) was issued an Order by the Federal Energy Regulatory Commission (FERC) approving the Settlement Agreement and issuing a new license for the Willamette Falls Project. Contained in the new FERC license is "Ordering Paragraph E" which makes the conditions submitted by the National Marine Fisheries Service (NMFS) under section 18 of the Federal Power Act a requirement of the license. Among the conditions contained in the License is a stipulation that establishes downstream juvenile salmonids passage protection goals of greater than or equal to 98% survival for downstream migrating salmonids as they pass through the T.W. Sullivan powerhouse. Survival through the powerhouse (*i.e*., Powerhouse Performance) will be calculated using estimates of survival through each passage route and estimates of Fish Guidance Efficiency (FGE), a measure of the percent of fish passing the powerhouse through non-turbine routes. The results of survival tests are presented in another report (Karchesky *et al.* 2008a). This report is a brief overview and summary of the third year of testing FGE at the T.W. Sullivan plant with the newly constructed North Fish Bypass system (NFB) in operation.

2.0 METHODS AND MATERIALS

As in 2007 and 2008, passive integrated transponder (PIT) tags were used to evaluate the proportion of smolts passing through each passage route at the T.W. Sullivan powerhouse (Karchesky *et al.* 2007; Karchesky *et al.* 2008b). A PIT tag detection antenna was constructed specifically for the NFB and was installed in early 2007. The newly installed PIT tag antenna was similar to the existing antennas installed in the Unit 13 bypass between the Eicher screen and the evaluator catch tank (Figure 2).

As suggested by Skalski (2000), the PIT tag antennas were calibrated for detection efficiency concurrently with each individual test release. This was done to ensure that any variation in detection efficiency between replicates was accounted for and provided the most precise data for generating an overall estimate of FGE. Depending on the scenario tested, one or both antennas were calibrated during each test by releasing fish immediately upstream of the antenna.

As in previous evaluations, out-migrating hatchery Chinook and steelhead smolts used for testing FGE in the spring were collected from the Unit 13 bypass evaluator. All fish selected for tagging were anesthetized, measured for length, and then injected with a standard 12mm PIT tag using methods similar to those described in PGE (2006). One treatment and two calibration release sites were designated. Treatment fish were released into the forebay approximately 20 feet downstream of the main head gates through one of three release ports. Calibration fish were released immediately upstream of each PIT tag antenna.

The detection history of each individual fish was uploaded from each detection antenna to the PTAGIS database, operated by the Pacific States Marine Fisheries Commission (PSMFC). This database was queried and data were downloaded for analysis.

As in 2008, one primary test scenario (“normal operating condition”) was evaluated in spring 2009. Limiting the number of test scenarios allowed us to release a sufficient number of fish to achieve the desired level of statistical precision for an overall estimate of FGE under normal operating conditions (see T.W. Sullivan Final Survival Performance Report 2009). Under this scenario, all test fish were released while both bypasses were operating, with all turbine units on, and with flow through the NFB set at 400 cfs. However, due to unplanned operational changes at the powerhouse, some fish were released under conditions outside of the primary test scenario in spring 2009. These releases were not subsequently combined with 2008 data and are only reported in this report.

Guidance efficiency data collected in spring 2009 under the normal operating scenario was combined with data collected in 2008 (Karchesky *et al.* 2008b) to establish an overall estimate of FGE (see T.W. Sullivan Final Survival Performance Report 2009). Passage efficiency of smolts released under conditions outside of the primary test scenario were analyzed based on the alternative likelihood model designed to estimate FGE through a dual bypass route (PGE 2006). This model accounts for the probability of detecting a fish (detection efficiency) at both antennas. The model compares these detection probabilities to the number of treatment fish released to the number of fish detected to derive an adjusted estimate of FGE.

3.0 RESULTS

3.1 Overview

Testing in spring 2009 began on 20 March using juvenile Chinook salmon and was followed by 6 subsequent releases (Table 1). All testing of Chinook salmon during the spring was completed by 23 April. As the number of juvenile Chinook collected at the bypass declined and the number of juvenile steelhead increased, tagging effort shifted from Chinook to steelhead. The initial FGE test using steelhead was conducted on 24 April and testing with steelhead continued through 29 May (Table 2). A total of five releases using steelhead were conducted. Testing was suspended when the number of steelhead collected in the Unit 13 evaluator decreased to a point that did not allow further collection or testing.

A total of 6,101 hatchery reared Chinook (3,391 treatment, 1,466 NFB calibration, and 1,244 Unit 13 calibration) and 2,004 steelhead smolts (1,033 treatment, 736 NFB calibration, and 235 Unit 13 calibration) were tagged and released to evaluate FGE in spring 2009 (Table 1). Juvenile Chinook were generally smaller than steelhead, with a fork length averaging 150 mm, and ranging from 93 mm to 223 mm (Figure 3). Steelhead averaged 221 mm and ranged from 165 to 320 mm in length.

3.2 Hydraulic Conditions

In spring 2009, average daily river flow recorded during each release trial varied among releases and between species; daily river flow ranged from approximately 18Kcfs to nearly 60Kcfs (Figure 4). Operational head (difference between the forebay and tailrace water elevation) ranged from 37.8 to 42.7 ft (Table 2). Water temperatures recorded during the spring evaluation period gradually increased from 8.9^{o} C to 17.2^{o} C.

3.3 PIT Tag Reader Efficiency

Detection efficiencies varied between PIT tag antennas (*e.g.*, NFB and Unit 13) and between fish species similar to those reported in 2007 and 2008 (Table 1; Karchesky *et al.* 2007; Karchesky *et al*. 2008b). As in previous years, detection efficiencies were higher for juvenile Chinook passing through the Unit 13 bypass (averaging 90.6%) when compared to those passing through the NFB (averaging 84.3%). Detection efficiencies for juvenile steelhead were more consistent between antennas. The average detection efficiency for steelhead passing through the Unit 13 bypass was 93.1% and through the NFB was 91.7%.

3.4 Fish Guidance Efficiency

For this report, individual FGE estimates were not calculated for groups released under the normal operating conditions; these data were combined with similar data collected in 2008 (Karchesky *et al*. 2008b) to establish an overall estimate of FGE (see T.W. Sullivan Final Survival Performance Report 2009). In total, six release groups of juvenile Chinook and three groups of steelhead representing 5,312 and 1,424 fish, respectively, were released under normal operating conditions in spring 2009.

While most of the release trials were tested under normal operating conditions, unplanned operational changes at the powerhouse and low flow resulted in some of the groups being released under conditions different to the primary test scenario.

During the April 23 release trial of juvenile Chinook, the Unit 13 turbine was not operating, although the Unit 13 bypass continued to be operated at 40 cfs. All other the turbine units were on and the NFB was operating at 400 cfs. This treatment group consisted of 512 smolts, of which 387 were detected passing through the NFB and one was detected passing through the Unit 13 Bypass. After adjusting for detection efficiency at each antenna, the estimated FGE under this atypical condition was 84% with an associated 95% confidence interval of 11%.

Two release trials of steelhead were released while some turbine units were offline, but all other conditions were normal (*i.e.,* NFB operating and flow set at 400 cfs; and Unit 13 bypass operating). On April 30, 203 treatment fish were released upstream while Units 4 and 9 were offline. After adjusting for detection efficiency, the estimated FGE under this atypical condition was 97% with an associated 95% confidence interval of 19%. On May 29, 76 steelhead were released while Units 3 and 9 were offline. Under this atypical condition, FGE was estimated to be 96% with an associated 95% confidence interval of 25% after adjusting for detection efficiency.

4.0 DISCUSSION

The objective of this third year of post-construction evaluation of the NFB and Unit 13 fish bypasses was to further refine the estimate of FGE for hatchery reared spring Chinook and steelhead smolts. In total, 5,312 juvenile Chinook and 1,424 steelhead were released under normal operating conditions and subsequently combined with 2008 data to estimate overall powerhouse performance (see T.W. Sullivan Final Survival Performance Report 2009).

In spring 2009, average detection efficiencies were slightly higher than those reported in 2008 for both species. In addition, the amount of variation in detection efficiencies among calibration trials was reduced. For instance, detection efficiencies for juvenile Chinook at the Unit 13 antenna ranged from 81% to 94% in 2009, while in 2008, detection efficiencies ranged from 68% to 100%. This was likely attributed to continuing to improve electrical noise identification and control, which allowed for more consistent antenna operation in spring 2009. In addition, we increased the number fish released during each trial in 2009 compared to previous years. This ultimately resulted in fewer release trials having more fish, which probably contributed to the reduced variation among detection efficiencies.

While we intended to release all fish under the normal operating condition in spring 2009, unexpected operational changes resulted in a few release trials being released under atypical conditions. For juvenile Chinook, a single release trial was released while all turbine units were operating except Unit 13. During this test the Unit 13 Bypass remained configured to allow approximately 40 cfs to continue to flow through the evaluator to prevent stranding. This made it possible for fish to pass through the Unit 13 Bypass while the turbine unit was offline. Under this configuration, estimated FGE for this release trial was consistent with previous releases conducted with Unit 13 offline and bypass closed (Karchesky *et al*. 2007). It is likely that even with 40 cfs continuing to pass through the bypass when the turbine is offline, fish are still able to hold behind the debris racks in front of Unit 13 when only the NFB is operating.

Estimates of FGE remained greater than 95% for steelhead even when various turbine units were offline. While further testing may be necessary, these results suggest that FGE for steelhead will remain high when various turbine units are offline.

5.0 REFERENCES

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Exhibit C

TABLES

Exhibit C

Table 1.

Summary of Chinook and steelhead smolts PIT-tagged and released immediately upstream of the T.W. Sullivan Powerhouse to evaluate FGE, spring 2009.

CHINOOK

Release Group	Tagging Date	Release Date	Species	NFB Calibration Released	NFB Calibration Detected	NFB Calibration %	Unit 13 Calibration Released	Unit 13 Calibration Detected	Unit 13 Calibration %	Treatment Released	Treatment NFB	Treatment Unit 13
1	19-Mar	20-Mar	Chinook	277	232	83.8	248	226	91.1	432	341	18
2	26-Mar	27-Mar	Chinook	60	45	75.0	60	54	90.0	244	162	22
3	2-Apr	3-Apr	Chinook	179	156	87.2	179	168	93.9	625	449	57
4	8-Apr	9-Apr	Chinook	238	192	80.7	237	222	93.7	542	405	33
5	9-Apr	10-Apr	Chinook	236	198	83.9	241	196	81.3	498	415	30
6	16-Apr	17-Apr	Chinook	239	214	89.6	239	219	91.7	538	451	21
7 [a]	22-Apr	23-Apr [b]	Chinook	237	214	90.3	40	37	92.5	512	387	1

STEELHEAD

Release Group	Tagging Date	Release Date	Species	NFB Calibration Released	NFB Calibration Detected	NFB Calibration %	Unit 13 Calibration Released	Unit 13 Calibration Detected	Unit 13 Calibration %	Treatment Released	Treatment NFB	Treatment Unit 13
1 [a]	29-Apr	30-Apr [c]	Steelhead	106	99	93.4	119	116	97.5	203	178	6
2	5-May	6-May	Steelhead	150	139	92.7	20	18	90.0	190	162	5
3	14-May	15-May	Steelhead	251	224	89.2	50	45	90.0	298	276	2
4	21-May	22-May	Steelhead	167	153	91.6	32	26	81.5	266	255	1
5 [a]	28-May	29-May [d]	Steelhead	62	61	98.4	14	14	100	76	72	0

[a] Powerhouse configuration was outside the “normal” operating condition; therefore data was not used to estimate powerhouse performance.

[b] Unit 13 turbine offline, Unit 13 Bypass operating at 40 cfs.

[c] Units 4 and 9 offline.

[d] Units 3 and 9 offline.

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Table 2.

Summary of conditions recorded during each treatment released at the T.W. Sullivan Powerhouse, spring 2009.

Release date	Species	Water Temp C	River flow (Kcfs)	Trailrace elevation (MSL)	Forebay elevation (MSL)	Operational head (ft)	NFB flow (cfs)	Unit 13 flow (cfs)	Weather Code[a]
3/20/2009	Chinook	8.9	35.8	11	52	41	400	40	3
3/27/2009	Chinook	8.9	35.5	11.5	52	40.5	400	40	3
4/3/2009	Chinook	8.9	35.3	9.5	52.2	42.7	400	40	2
4/9/2009	Chinook	11.6	28.9	10.75	52	41.25	400	40	3
4/10/2009	Chinook	11.7	29.6	11.75	52	40.25	400	40	2
4/17/2009	Chinook	10.0	25.5	10.5	51.2	40.7	400	40	3
4/23/2009	Chinook	13.9	25.2	11	52	41	400	40	2
4/30/2009	Steelhead	11.7	21.4	11	50.8	39.8	400	40	1
5/6/2009	Steelhead	13.3	48.4	12.8	52.8	40	400	40	3
5/15/2009	Steelhead	13.3	37.8	12.5	52.6	40.1	400	40	1
5/22/2009	Steelhead	15.6	25.7	13.5	52	38.5	400	40	1
5/29/2009	Steelhead	17.2	18.4	13	50.8	37.8	400	40	1

[a] Weather code: 1 sunny; 2 partly cloudy; and 3 cloudy.

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FIGURES

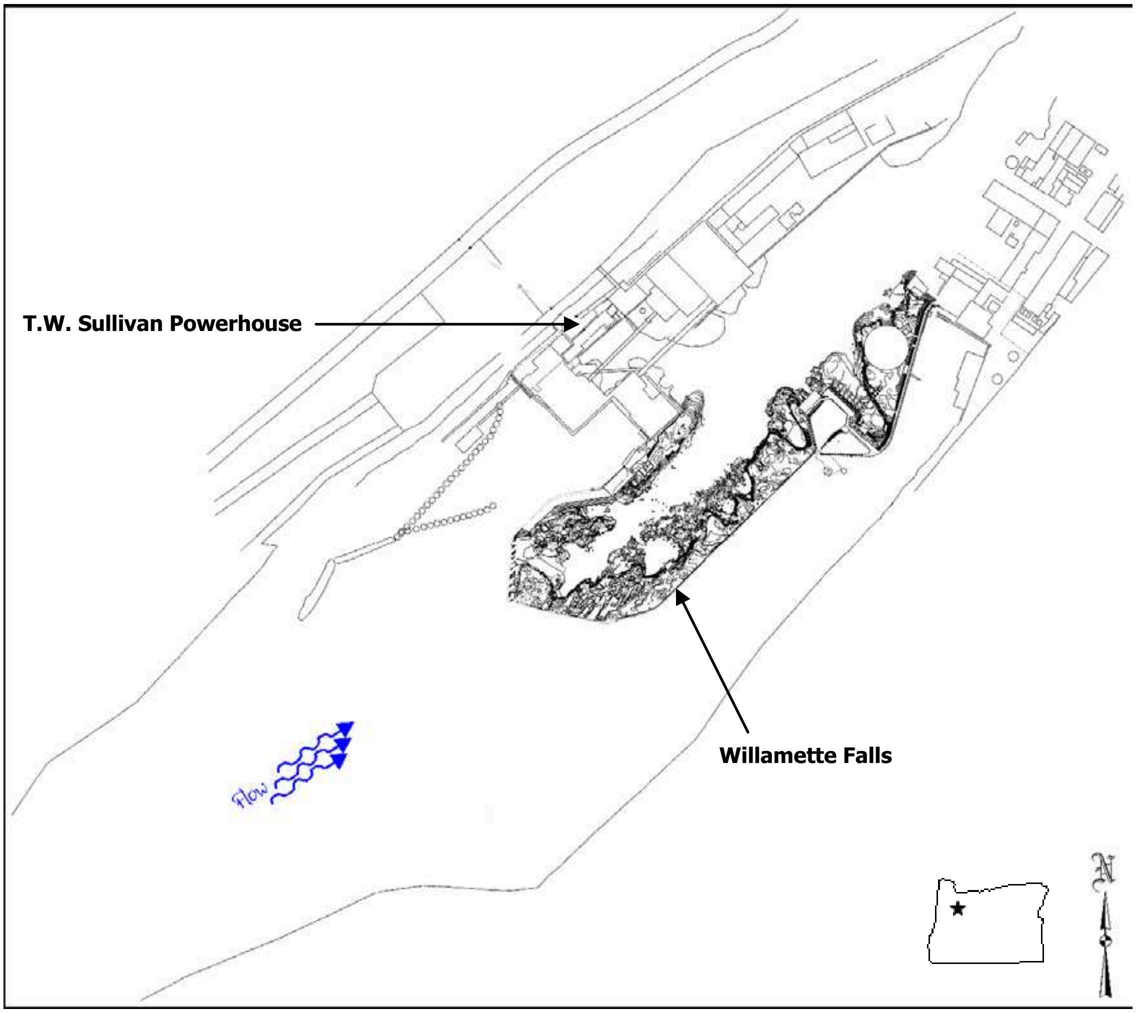

Figure 1.
Generalized layout of the Willamette Falls Project.

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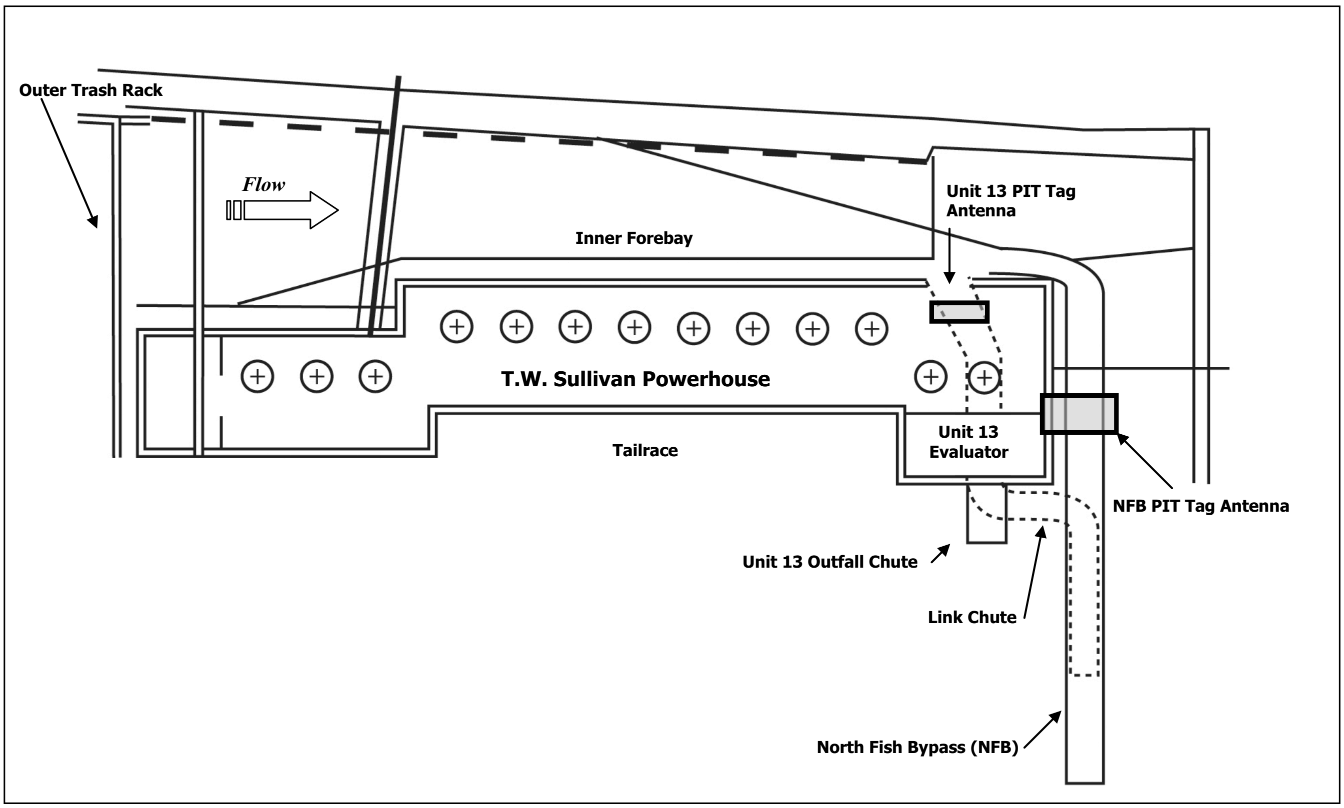

Figure 2.

T.W. Sullivan forebay and fish bypass facilities.

Exhibit C

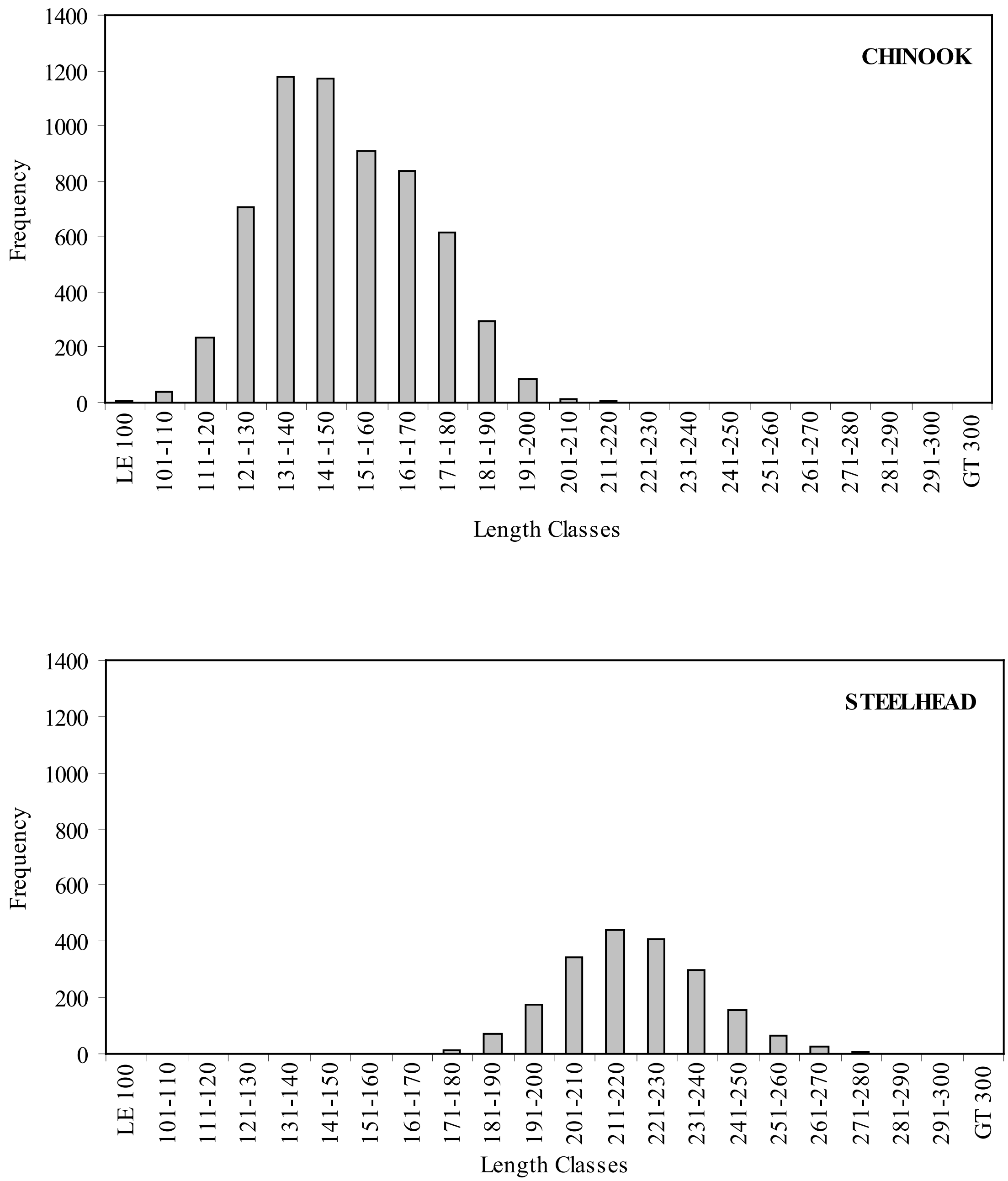

Figure 3.

Length frequency distribution of juvenile Chinook and steelhead tag and release at the T.W. Sullivan powerhouse to estimate FGE, spring 2009.

Exhibit C

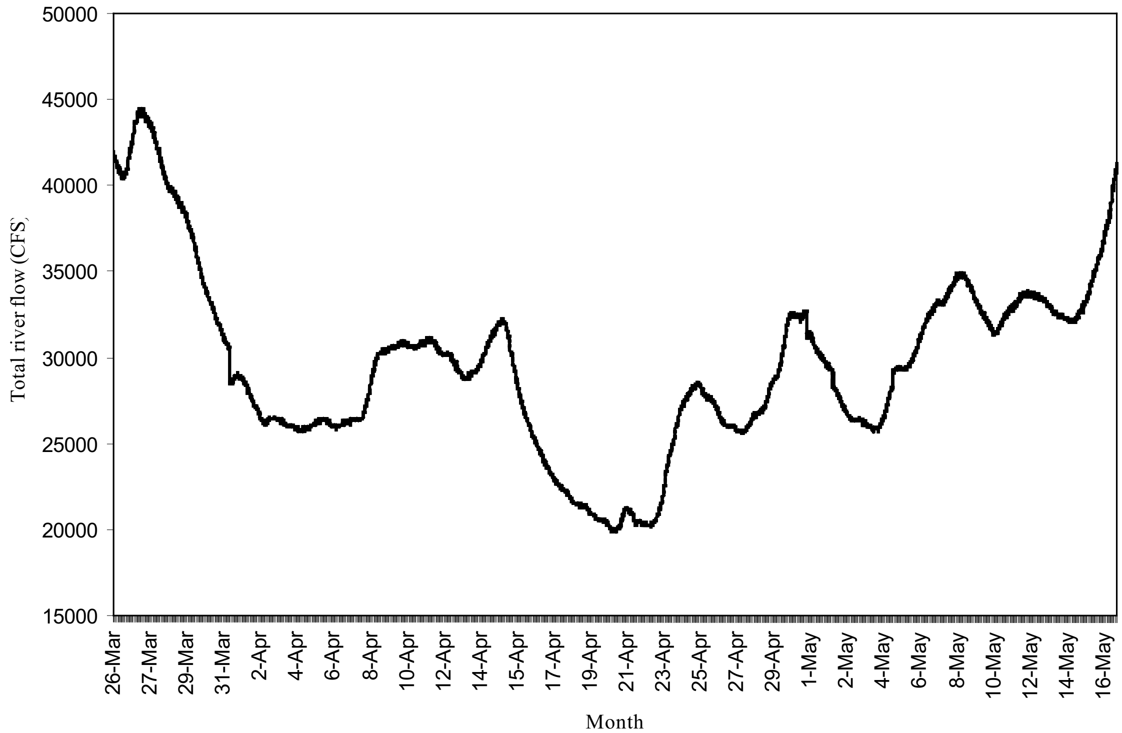

Figure 4.

Average daily river flow recorded at the USGS gauging station located upstream of Willamette Falls and adjusted for accretion recorded during the FGE evaluation period, spring 2009.

Exhibit D

Estimating survival and condition of juvenile salmonids after passage through the fish bypass system at the T. W. Sullivan Hydroelectric Project, Willamette River, OR, 2008

Exhibit D

FISH TECHNICAL COMMITTEE REVIEW DRAFT REPORT

ESTIMATING SURVIVAL AND CONDITION OF JUVENILE SALMONIDS AFTER PASSAGE THROUGH THE MODIFIED FISH BYPASS SYSTEM AT THE T. W. SULLIVAN HYDROELECTRIC PROJECT, WILLAMETTE RIVER, OR.

SPRING 2008

PREPARDED FOR:
Portland General Electric Company

PREPARED BY:
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September 2008

Exhibit D

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This study should be cited as: Karchesky, C.M., R.D. McDonald, P.G. Heisey, S.W. Adams, and S.N. Graver. 2008. Estimating survival and condition of juvenile salmonids after passage through the fish bypass system at the T. W. Sullivan Hydroelectric Project, Willamette River, OR. Prepared for Portland General Electric (PGE), Portland, OR.

EXECUTIVE SUMMARY

The purpose of this study was to estimate immediate (1 hr) and latent (48 hr) survival and injury for juvenile Chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss* following passage through the downstream fish bypass systems at the T.W. Sullivan Hydroelectric Project, located at Willamette Falls on the Willamette River, OR. HI-Z Turb`N Tag® technology was used to evaluate fish condition immediately after passage through the newly constructed North Fish Bypass (the NFB), the Unit 13 Bypass Link Chute, and the modified Unit 13 Outfall Chute. This technology involves the release of live fish upstream (treatment group) and downstream (control group) of a particular passage route. Tagged fish are then recaptured downstream after passage upon inflation of the HI-Z tags. The ability to recapture fish after passage allows for the condition of individual fish to be directly assessed and their fate determined immediately after passage. All recaptured fish are held for 48 hrs to assess any delayed passage effects.

An additional assessment of fish condition following passage through the inner forebay and upper portion of the Unit 13 Bypass was conducted using a mark-recapture approach. Hatchery juvenile Chinook and steelhead of known condition were fin-clipped, released immediately upstream of the inner forebay and then recaptured in the evaluation facility following passage through the upper portion of the Unit 13 Bypass. Fish were assessed for injury and held for 48 hours to develop estimates of injury and relative survival following passage through this upper section of the bypass.

The HI-Z tag evaluation was conducted over a twelve day period from 3 March to 14 March, 2008. A total of 2,517 fish (1,296 Chinook and 1,221 steelhead) were released during this evaluation from which an analytical sample of 2,123 fish (941 Chinook and 1,182 steelhead) was used to estimate direct survival and injury for each species. Two primary test scenarios were tested using HI-Z tags. The first test scenario evaluated the two species of juvenile salmonid passing through the NFB at 400 cfs flow. The second test scenario evaluated fish condition following passage through the Link Chute with 400 cfs passing through the NFB. Additional testing was also conducted at a lower test flow of 250 cfs passing through the NFB for each scenario, and for fish passing the through the modified Unit 13 Outfall Chute. Juvenile Chinook released as a part of these evaluations were generally smaller than the steelhead with a mean length of 153 mm; the mean length for juvenile steelhead was 193 mm.

Passage survival probabilities derived from the HI-Z tag evaluation for each test scenario were estimated relative to control fish survival to calculate immediate and latent survival. A likelihood ratio test was used to determine whether recapture probabilities were similar for alive and dead fish. The desired level of precision for the primary test flows evaluated during this study was $\leq \pm 2.5\%$, 95% of the time ($\alpha = 0.05$).

Two malady rates (*i.e.,* fish having physical injuries, greater than 20% scale loss, and/or swimming erratically) were calculated for each test scenario evaluated using HI-Z tags. The first rate (combined malady rate) included all fish having maladies classified as both minor and major, while the second malady rate (major only) only included those fish with maladies classified as major. Malady rates were calculated using only the fish that were recaptured and examined, rather than the total number of fish released. The probability of malady and associated standard error were estimated relative to control fish using the same likelihood model used to estimate survival probabilities.

The results of the HI-Z tag evaluation indicate that direct survival through the NFB and the Link Chute at the T.W. Sullivan project is high. Recapture rates of fish (physical retrieval of alive and dead fish after passage) were in excess of 98% for all test scenarios. Immediate (1 hr) and latent (48 hr) survival

probabilities for juvenile Chinook salmon passing the NFB and the Link Chute at both flows tested (400 and 250 cfs) were 100%. Immediate (1 hr) and latent (48 hr) survival estimates were also near 100% for steelhead passing through the NFB and Link Chute at both flow conditions tested. The lowest survival (98.4%) was calculated for steelhead passing through the Link Chute with 400 cfs passing through the NFB. None of the juvenile steelhead released through the modified Unit 13 Outfall Chute were recovered dead or died during the 48 hr holding period. As a result, the immediate (1 hr) and latent (48 hr) survival rates for this route were 100%. The 95% confidence intervals surrounding the survival estimates ranged from 0.7% to 2.8%.

Overall, malady rates of juvenile salmonids passing through the NFB and Link Chute were low. The highest combined malady rate was 1.6 %, which was calculated for steelhead passing through the Link Chute at the lower NFB flow of 250 cfs; all other malady estimates (both combined and major malady only) were less than 1 %. The 95% confidence intervals surrounding the malady rates ranged from 0.7% to 2.7%. Visible maladies observed during this study (n = 11) included physical injury (operculum damage, external scrapes and bruises, and internal hemorrhaging), and loss of equilibrium; some fish had multiple maladies. Most maladies associated with passage through the Link Chute were characterized as being caused by mechanical forces, whereas maladies associated with passage through the NFB and Unit 13 Outfall Chute were characterized as being caused by shear force (or sudden changes in water velocity). However these apparent differences are likely only generalizations since overall the numbers of maladies observed were low.

The mark-recapture evaluation designed to assess fish condition following passage through the inner forebay and upper portion of the Unit 13 Bypass was conducted over a 5 day period (18 March to 23 March), which followed the HI-Z tag evaluation. A total of 629 hatchery reared Chinook salmon (515 treatment and 114 control) and 479 steelhead smolts (349 treatment and 130 control) were marked and released at the head of the trash racks leading into the inner forebay (treatment), or directly into the evaluator catch tank (control).

A total of 246 marked Chinook smolts and 89 juvenile steelhead were recaptured and examined following passage through the inner forebay and the upper portion of the Unit 13 Bypass. Only one of the Chinook smolts recaptured and held died during the holding period resulting in a latent (48 hr) survival estimate of 99.6%. No steelhead were recovered dead or died during the 48 hour holding period, resulting in a survival estimate of 100%.

Overall, the combined malady rate estimated during the mark-recapture assessment was slightly higher for Chinook smolts than for juvenile steelhead, although for both species this rate was less than 4%. Seven of the 246 Chinook smolts that were recaptured and examined were reported having a passage related malady resulting in a combined malady rate of 3.3%. When Chinook with only major injuries were considered, the injury rate was 1.6%. The combined injury rate for juvenile steelhead was 1.4%, and for steelhead with only major injuries, the injury rate decreased to 1.1%.

The dominant malady type for juvenile Chinook passing through the upper bypass reach was descaling, which appeared to be largely attributed to mechanical contact or abrasion with a solid object. The maladies observed on steelhead were characterized as bruising between the dorsal fin and head, and also appeared to be related to mechanical forces.

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1.0 INTRODUCTION AND BACKGROUND

Portland General Electric Company (PGE) contracted with Normandeau Associates, Inc. to conduct an evaluation to estimate the direct survival and condition of juvenile salmonids after passage through the newly modified Fish Bypass System of the T.W. Sullivan Powerhouse at the Willamette Falls Hydroelectric Project (FERC No. 2233).

The Willamette Falls Hydroelectric Project is located at river mile 26.5 on the Willamette River in northwest Oregon (Figure 1). The T.W. Sullivan powerhouse is located adjacent to Willamette Falls, a naturally occurring, horseshoe shaped 40-ft-high basalt rock formation with a low concrete gravity dam along its entire crest. Willamette Falls marks the upstream boundary of the tidally influenced section of the lower Willamette River. The powerhouse contains 13 turbines including 12 vertical-axis Kaplan-type turbines and one Francis-type turbine (Unit 9). Each turbine has an intake from the forebay and discharges into the tailrace, which flows into the main river channel just below Willamette Falls. Since the forebay of the powerhouse is oriented parallel with river flow, the fish bypass system at the project is designed to operate as a louver system. Fish entering the forebay are guided along the turbine intake trash-racks and exit near the northern end of the forebay through either the newly constructed North Fish Bypass (NFB) or through the existing Unit 13 bypass (Eicher screen system). The purpose of the NFB is to increase flows through the forebay so that velocities increase towards the bypass and to provide an additional opportunity for non-turbine downstream passage of fish that have entered the inner forebay. The NFB is located immediately downstream of and adjacent to Unit 13, and was designed to work independently or in conjunction with the existing Unit 13 bypass system (Figures 2 and 3). The NFB has a design flow capacity of up to 500 cfs and discharges downstream of the project into the tailrace (Figures 2 and 3). During construction of the NFB, the existing outfall of the Unit 13 Bypass system was modified by the construction of a “Link Chute” which transfers fish from the Unit 13 bypass into the outfall of the NFB (when the NFB is operating).

On 8 December 2005, PGE was issued an Order by the Federal Energy Regulatory Commission (FERC) approving the Settlement Agreement and issuing a new FERC license for the Willamette Falls Project. Contained in the new FERC license is “Ordering Paragraph E” which makes the conditions submitted by the National Marine Fisheries Service (NMFS) under section 18 of the Federal Power Act a requirement of the license (Appendix B to the License). Conditions in Appendix B stipulate a performance standard for downstream migrating juvenile salmonids of greater than 98% survival as they pass through the structures related to the modifications at the Willamette Falls Project. The objectives of the current investigation are a portion of the post construction evaluation of the new NFB and modified Unit 13 fish bypass as outlined in the Sullivan Performance Study Plan (PGE 2006). The primary objective of this evaluation is to estimate survival and injury of hatchery reared spring Chinook *Oncorhynchus tshawytscha* and steelhead *O. mykiss* smolts through both bypasses to evaluate bypass performance relative to the mandatory conditions contained in Appendix B of the new FERC license.

For the purpose of testing fish survival and condition, the combined bypass system was divided into three sections as indicated in the Sullivan Performance Study Plan (PGE 2006): 1) the new NFB section; 2) the Unit 13 Reach–One section extending from inner trash racks at the entrance of Unit 13 to immediately downstream of the fish evaluator; and 3) the Unit 13 Reach–Two section (also known as the “Link Chute”) extending immediately downstream of the fish evaluator to the exit of the NFB outfall chute (Figure 4). Direct survival and injury of juvenile salmonids passing through the NFB and Link Chute were assessed using Normandeau Associates' patented technique known as HI-Z Turb`N Tag® (HI-Z Tag) technology. Since the configuration of the upper portion of the Unit 13 bypass is not conducive for the use of HI-Z tags, a mark-recapture study was designed to evaluate fish condition and survival following passage through Reach-One. Aspects of these evaluations were developed based on the expected recapture rates of fish and other information obtained from PGE biologists, during site visits to the Willamette Falls Project, and consultation from the Fish Technical Committee (FTC[1]). The specific objectives of this study were to:

Objective 1. Estimate immediate (1 h) and latent (48 h) direct survival, malady, and identify potential sources of malady for juvenile salmonids following passage through the NFB;

Objective 2. Estimate immediate (1 h) and latent (48 h) direct survival, malady, and identify potential sources of malady for juvenile salmonids passing through the Link Chute in the lower section (Reach-Two) of the Unit 13 bypass, which connects the Unit 13 Bypass Evaluator to the outfall of the NFB; and

Objective 3. Estimate survival and malady of juvenile salmonids following passage through the inner forebay and upper section (Reach-One) of the Unit 13 bypass, which extends from the entrance of the Unit13 Bypass to the fish evaluator.

2.0 MATERIALS AND METHODS

To assess direct fish survival and malady rates through the NFB and Link Chute, Normandeau Associates' HI-Z tag was employed (Heisey *et al.* 1992).

The HI-Z tag technology involves the release of live fish upstream (treatment group) and downstream (control group) of a particular passage route. These fish are then recaptured downstream after passage and inflation of the HI-Z tags. The ability to recapture fish after passage allows for the condition of an individual fish to be directly assessed and their fate determined after passage. All recaptured fish are held and monitored for 48 hrs following recapture to assess the delayed effects of passage. The statistical precision of the survival estimate obtained with this technology is largely driven by the recapture rates of the tagged fish and control group survival.

Two primary test scenarios were tested using HI-Z tags (Objectives 1 and 2). The first test scenario evaluated two species of juvenile salmonid (spring Chinook salmon and steelhead) passing through the NFB at 400 cfs flow. The second test scenario evaluated the passage of juvenile Chinook and steelhead passing through the Link Chute (Reach-Two) with 400 cfs passing through the NFB. Additional testing of each scenario at a lower NFB flow (*i.e.,* 250 cfs) and passage through the modified Unit 13 Outfall Chute were also scheduled if time, river flow, fish availability, and statistical precision of the primary test scenarios allowed.

[1] The Fish Technical Committee (FTC) is comprised of interested signatory parties to consult and advise PGE on fisheries related issues and implementation of the license order measures.

A mark-recapture study using acquired fish without physical injuries or descaling was used to evaluate fish condition and survival following passage through the inner forebay and Reach-One, the upper section of the Unit 13 bypass (Objective 3). This approach was developed after the results of the 2007 evaluation of Reach-One (Karchesky *et al*. 2007a) indicated a difficulty in discerning whether the injuries (particularly descaling) observed on run-of-the-river smolts randomly collected in the bypass were passage related, or whether they occurred prior to entering the powerhouse. The use of acquired fish, which were free of injury, allowed for a more accurate assessment of the type and severity of injuries that occurred during passage as well as the potential causal mechanisms.

The methods used to evaluate fish condition and survival through Reach-One were similar to those used during studies conducted between 1991 and 1997 (PGE 1998), except hatchery fish of known origin and condition were released and evaluated rather than randomly selected run-of-the-river fish. Juvenile Chinook and steelhead free of injuries and obtained from a hatchery were marked with a fin-clip and released at the head of the trash racks leading into the inner forebay. A portion of these fish were then recollected downstream at the Unit 13 evaluator following passage through the inner forebay and Reach-One of the Unit 13 Bypass. The condition of recaptured fish was assessed using methods similar to those described in PGE (2006).

2.1 Hydraulic Conditions

Total river flow was measured hourly at a USGS Gage site located approximately 57.7 miles upstream of the project (USGS gage no. 14191000 at RM 84.16, Willamette River at Salem, OR). An adjustment factor was applied to hourly flows to account for accretion between the USGS Gage at Salem and Willamette Falls. Daily forebay and tailrace elevations were obtained from PGE.

2.2 HI-Z Tag Evaluation (Study Objectives 1 and 2)

2.2.1 Fish Procurement and Holding

Juvenile Chinook and steelhead smolts were obtained from the Oregon Department of Fish and Wildlife Clackamas Fish Hatchery and from the Bonneville Dam Fish Hatchery, respectively. Only fish in good physical condition and free of injury were used in the evaluation. All fish were transported to the tagging site at Willamette Falls by PGE biologists using an oxygenated fish hauling trailer. Prior to tagging, all fish were held for a minimum of 24 hrs after transport to allow for full recovery from the stress associated with capture and transport. To avoid potential predation or stress, each species was held separately for the duration of the study. Prior to tagging, test fish were held in one of two 700 gallon circular tanks continuously supplied with ambient river water and covered to prevent escapement.

2.2.2 Fish Tagging and Release

To assure that all treatment and control fish were of a similar size and condition, all fish designated to be tagged with HI-Z tags were selected randomly from the holding tanks each day. Selected fish were transported to the tagging site and held overnight prior to tagging**.** All procedures for fish handling, tagging, release, and recapture were identical for treatment and control groups.

Tagging techniques were identical to those previously used at PGE's North Fork Dam (Heisey *et al.* 2002), River Mill Dam (Karchesky *et al.* 2007b) and other studies using juvenile salmonids in the Columbia River Basin (Mathur *et. al*. 1999; Normandeau Associates *et al.* 2004; Normandeau Associates and Skalski 2005, 2006a, b; Heisey *et al.* 2008). Briefly, groups of 5 to 10 fish were removed from the holding tank in the tagging facility. Fish displaying abnormal behavior, signs of injury or disease, fungal infection, or major descaling (greater than 20% on either side) were not tagged.

While anesthetized in a solution of clove oil, test fish were measured to total length (TL), and equipped with two uninflated HI-Z tags and a miniature radio tag (in conjunction with the dorsal balloon tag; Figure 5). Two stainless steel pins secured the tags to the musculature of the fish below the dorsal and adipose fins. A uniquely numbered Visual Implant tag (VI tag; Northwest Marine Technology, Inc., Shaw Island, WA) was inserted in the post ocular tissue to allow for individual identification of each test fish. Fish were also marked with a unique fin clip to distinguish fish released under various test conditions each day. Immediately after tagging, fish were held in a covered 10 gallon tub that was continually supplied with ambient river water until they were fully recovered from the anesthesia. Once recovered, the fish were transported to the release site where the tags were activated and the fish were individually released. HI-Z tags inflated in approximately 2 to 3 minutes after passage.

All fish that passed through the NFB, or were released as control fish, were released through an induction apparatus that consisted of a small holding basin attached to a submersible pump and a 4-in diameter flexible release hose. Fish passed through the NFB were released through an induction system located on the forebay deck near the entrance to the NFB (Figure 6). The control release site was moved during the study in an attempt to reduce the number of fish that became entrapped. The initial control release site was located in the tailrace immediately under the Unit 13 Outfall Chute (Figure 7). However, some fish released at this location became entrapped under the NFB outfall chute after their tags inflated. Consequently, the control site was relocated approximately 20 m downstream and on the opposite side of the river adjacent to the adult fish ladder (Figure 8). Because of the limited space available in the Unit 13 evaluator, it was not possible to release fish into the Link Chute using a traditional induction system. Therefore, fish were manually released into the entrance of the Link Chute by gently dropping the fish into the water just upstream of the weir delineating the upper and lower reaches of the Unit 13 Bypass (Figure 9).

2.2.3 Fish Recapture

Following release, HI-Z tagged fish were recaptured once the tags inflated downstream of the project by boat crews using dip nets equipped with a water sanctuary. Upon recapture, inflated tags were removed, and each fish was examined. Each fish was then assigned the appropriate condition code. This code categorized physical injuries or other maladies by the type, extent, and area of body where it occurred (Table 1). Maladies which were known or suspected to be caused by a predator or those attributed to the tag (*e.g.,* tearing at the tag site) were recorded but were not included in the analysis. Data recording personnel were notified via a two-way radio of the recapture time and condition of each recovered fish. To minimize any potential crew bias, no specific individual was specifically assigned to retrieve only control or treatment fish.

Retrieval time for each recovered fish was calculated as the difference between the release time and the corresponding recapture time. To decrease the influence of outlying data points, retrieval times were evaluated based on median as opposed to mean time.

All fish recaptured alive were transferred from the boats in 5 gallon buckets to a covered pool, where they were held for 48 hrs to assess delayed mortality. All treatment and control fish of the same species released during a particular day were held in the same holding pool. Fish were checked routinely over the duration of the 48 hr period to insure that there was sufficient flow into the holding pools and to remove any dead fish.

2.2.4 Classification of Test Fish

Immediately following passage, each HI-Z tagged fish was classified as alive, dead, malady, or unknown. These classifications were defined as:

1. alive – recaptured alive and remained alive for at least 1 hr following capture;
2. dead – recaptured dead, died within 1 hr of release, only inflated tag(s) were recovered (without fish), or a stationary radio signal was detected in the tailrace;
3. malady – recaptured with a physical injury, or had greater than 20% scale loss along either side, or was not actively swimming or swimming erratically upon recapture; and
4. unknown – no fish or dislodged tags were recaptured, or radio signals were received only briefly, and the subsequent status cannot be ascertained.

Recaptures rates were calculated for each scenario based on the number of alive and dead fish physically retrieved compared to the total number of fish released in the analytical sample. Fish whose location was known but were impossible to recapture (*i.e.,* those entrapped in rip-rap along the shoreline, or under the outfall chute) were replaced in the sample. These replaced fish were not included in the subsequent calculations of survival and malady rates. Fish recaptured dead or those that died within 1 hr of recapture were designated as 1 hr post-passage mortality. Fish that died between 1 hr and 48 hrs following passage were designated 48 hr post-passage mortality. All fish that died following passage were necropsied to assess the probable cause of death.

All injuries to fish were further categorized based on the severity of the injuries and were designated as either major or minor following the procedures established in limited laboratory studies (Pacific Northwest National Laboratory *et al.* 2001) and outlined in Normandeau and Skalski (2007):

- Major – Visible injuries/maladies classified as major include: ≥50% hemorrhaged eye, deformed/ruptured bulging pupil; opercula tear ≥5 mm; folded or torn off operculum; bruise/scrape (damage to epidermis) ≥10% per side of the fish; cuts and lacerations; internal hemorrhage/rupture of organs and/or damaged spinal column that result in death (1-48 hr); scale loss ≥20% per side of fish; loss of equilibrium if fish dies within 1 hr; any injury/malady that results in death ≤1 hr. Also fish with no apparent injury/malady that die ≤1 hr.

- Minor – All visible injuries/maladies that are less severe/extensive then those designated major and do not result in death $\leq$1 hr; some specific designations include minor bulging eye, small flaps of skin and scrape on snout. Additionally loss of equilibrium that results in no death or death $\geq$1 hr. A fish with no apparent injury/malady that dies $\geq$1 hr is also given a minor classification but not considered to have a passage related injury.

Following the 48 hr holding period, all live fish were anesthetized and closely examined for injury. Fish were anesthetized to minimize handling effects and associated stress, and to allow closer examination. The initial examination immediately following recapture allows detection of some injuries, such as bleeding or minor bruising that may not be evident after 48 hrs due to natural healing processes (Heisey *et al.* 1992). However, during the 48 hr examination delayed injuries, such as an eye hemorrhages, may become more apparent. Any fish injuries identified during the 48 hr evaluation were also categorized by type, extent, and area of the body. Photographs of injured fish were taken if the fish died or after the 48 hr holding period if an injury to a live fish was still evident. Following examination and recovery from anesthesia, all live fish free of maladies were returned to the river via the fish ladder at Willamette Falls.

The type of injury observed was compared with previous data from controlled experiments designed to replicate and correlate injury type and characteristics to a specific causative mechanism to determine the probable source of affliction for injured fish (Neitzel *et al.* 2000; Pacific Northwest National Laboratory *et al.* 2001). However, some types of injury symptoms can be related to different causal mechanisms, making it difficult to accurately determine the cause of some injuries (Eicher Associates 1987). Therefore, only probable causative mechanisms of injury were assigned; those caused by mechanical or shear related events.

2.2.5 Data Analysis

2.2.5.1 Survival Probabilities

Based on the pre-study assumptions regarding recapture and control survival rates, a sufficient number of fish were HI-Z tagged and released so that resulting survival estimates would be within the desired level of precision (ε) of ± 2.5%, 95% of the time.

Passage survival probabilities for each test scenario were estimated relative to the control fish survival to calculate immediate (1 hr) and latent (48 hr) survival. A Chi-square test was used to determine whether the data from each of the daily trials could be pooled to test for homogeneity ($\alpha = 0.05$) in each treatment release with respect to recapture probabilities of alive, dead, and non-recovered fish.

A likelihood ratio test was used to determine whether recapture probabilities were similar for alive (P_A) and dead (P_D) fish (RMC and Skalski 1994a, b). The statistic tests the null hypothesis of the simplified model (H_0: $P_A = P_D$) versus the alternative of the generalized model (H_a:$P_A \neq P_D$; Appendix A). Depending on the outcome of this analysis, the parameters and their associated standard errors were calculated using the appropriate model.

The 95% confidence interval on the estimated survival was calculated using the profile likelihood method (Hudson 1971). This profile method constructs confidence intervals without assuming normality for passage survival, and is generally assumed superior to using approximations based on a normal distribution (Appendix A).

2.2.5.2 Malady Rates

Malady rates (*i.e.*, fish having physical injuries, greater than 20% scale lose, and/or swimming erratically) were calculated using only the fish that were recaptured and examined, rather than the total number of fish released. Furthermore, only maladies related to passage through the NFB or the Link Chute were included in the calculation. Fish having passage related maladies that subsequently died during holding were also included. The malady rates and associated standard errors were estimated relative to control fish using the same likelihood model as for estimating survival probabilities (Appendix A).

2.3 Mark Recapture Evaluation (Objective 3)

2.3.1 Fish Marking and Release

Juvenile Chinook and steelhead were obtained similar to those for the HI-Z evaluation from the Oregon Department of Fish and Wildlife Clackamas Fish Hatchery and from the Bonneville Dam Fish Hatchery, respectively. Fish in good physical condition and free of injury were divided into small groups and anesthetized in a solution of clove oil. Fish were then measured for fork length (FL) (mm) and marked with a unique fin clip to determine release group (treatment vs. control). Once marked, fish were immediately transferred to a series of perforated 32 gallon holding containers, and held in separate groups of 30 to 60 fish (depending on fish size). The holding containers were submerged in one of the two 700 gallon holding ponds located on the upper deck adjacent to the entrance of the NFB. Each submerged holding container was continuously supplied with ambient river water until the fish were released.

After marking, smolts were held overnight to ensure that all test fish were fully recovered prior to release. The fish designated to the treatment group were then released through an induction apparatus at the head of the trash racks leading into the inner forebay (Figure 2). Fish designated to the control group were divided into approximate thirds, and were released during each collection day directly into the evaluator catch tank (Figure 4).

2.3.2 Fish Recapture

Prior to release, flow through the NFB was shut off, and the Unit 13 evaluator was set in “fishing or sampling mode” to allow recapture of marked fish. Following passage through the inner forebay and Reach-One of the Unit 13 Bypass, marked fish were collected in the evaluator catch tank. Recaptured fish were then removed, anesthetized, and closely examined. Any observed maladies were categorized by type, extent, and area of the body. Once the examination was complete, fish were separated by species and placed into one of five covered holding tanks located in the Unit 13 evaluation facility where they were held for 48 hrs. All fish of the same species recaptured during a particular day (treatment and control) were held in the same holding tank. Fish were checked routinely over the duration of the 48 hr holding period to insure that there was sufficient circulation in the holding tank and to remove any dead fish. Marked fish were collected continuously over a 3 day period following the initial release. During this period all recaptured fin-clipped fish were held for 48 hrs.

Following the 48 hr holding period, each collection group of fish were again anesthetized and closely examined for injury. The initial examination immediately following recapture allowed for detection of some injuries, such as bleeding or minor bruising that may not be evident after 48 hrs due to natural healing processes. However, during the 48 hr examination delayed injuries such as an eye hemorrhage may be more apparent. Photographs of injured fish were taken if the fish died or after the 48 hr holding period if an injury to a live fish was still evident.

2.3.3 Data Analysis

Survival and malady rates of marked fish passing through Reach-One were analyzed similar to previous studies (PGE 1998), and included only fish recaptured in the evaluator catch tank. Recaptured fish were classified based on their condition following passage and upon recollection from the catch tank as:

1. alive – recaptured alive and remained alive during the 48 hr holding period with no sign of maladies;

2. dead – recaptured dead or died during the 48 hr holding period; and

3. malady – recaptured with a physical injury (*i.e.,* bruising or lacerations), or had greater than 20% scale loss along either side, or was not actively swimming or swimming erratically upon recapture.

Fish having maladies were further categorized based on the severity of their maladies, and were designated as either major or minor similar to HI-Z tagged fish and as described above in section 2.2.4.

Since this evaluation was intended as a general assessment of fish condition following passage through Reach-One, survival and malady estimates were derived as point estimates, but did not include calculations of precision. Survival rates were calculated as the total number of fish collected over the pre-specified time period divided by the number alive at recapture and living after the 48 hour holding period, and were adjusted based on control fish survival (*i.e.,* dividing the proportion of treatment fish surviving relative to the number of treatment fish released by the proportion of control fish surviving relative to the number of control fish released). Two malady rates were calculated and were based on the total number of fish recaptured having physical injury, scale loss, or loss of equilibrium, and were adjusted based on the malady rates of control fish. The first rate included all fish having maladies classified as both major and minor (combined malady rate), while the second malady rate only included those fish with maladies classified as major.

3.0 RESULTS

3.1 Hydraulic Conditions

Daily average river flow (adjusted for accretion) during the course of the 12 day HI-Z tag evaluation ranged from 21,195 cfs to 31,725 cfs (Figure 11), and was considerably lower than the historical average (period of record 1953-2007) recorded for this period (average 40,230 cfs). However, during the mark-recapture study conducted immediately following the HI-Z tag evaluation, average river flow increased substantially, ranging from 45,900 cfs to 63,492 cfs during the 5 day study. However, it should be noted that flow through the powerhouse is dictated by the hydraulic capacity of the project, not the total river flow, and a majority of the total river flow passes over Willamette Falls and not through the powerhouse or fish bypasses.

Ambient river temperatures remained consistent throughout the course of the 12 day HI-Z tag evaluation and mark-recapture study ranging from 7.0 to 9.0^{o} C.

Willamette Falls provides the upstream end of the tidally influenced portion of the Willamette River. Therefore, daily fluctuations in tailrace elevation observed during the study period were more related to diurnal stage of the tide than total river flow or project operations. Daily reading of the tailrace elevation recorded during the HI-Z evaluation ranged from 8.9 ft to 10.1 ft MSL. Daily reading of the tailrace elevation recorded during the mark-recapture study ranged from 12.0 to 14.5 ft MSL. The powerhouse operated consistently throughout both study periods with all units in operation.

3.2 HI-Z Tag Evaluation (Study Objectives 1 and 2)

3.2.1 Overview

Testing of the NFB and Link Chute using HI-Z tags began on 3 March, and was completed on 14 March 2008. In addition to the primary test flow of 400 cfs through the NFB, a second test flow of 250 cfs was evaluated for both passage routes using juvenile Chinook and steelhead. Also, given the available time and fish remaining, we evaluated the survival and condition of juvenile steelhead passing through the modified Unit 13 Outfall Chute (Figures 7 and 10). These supplementary releases were secondary to the primary objectives and were undertaken after primary statistical goals were thought to have been met. The sample size of this supplementary release were slightly below those required to meet the desired level of statistical precision (*i.e.,* ± 2.5%, 95% of the time) given the pre-specified study assumptions.

Not all daily release trials of fish were used in the final analytical data set because of disproportionately high non-passage related mortality and injury. Juvenile Chinook released on 4 March experienced a high level of avian predation. To deter avian predators in the test area that had learned to “key in” on inflated balloons, actions were taken later that day to reduce the number of birds in the tailrace and keep those birds that remained in the study area from preying on test fish. These actions included deployment of passive (*e.g.,* flash tape and bird wires) and active (*e.g.,* “bird bangers” and other pyrotechnics) bird deterrent devices. Although these actions did not entirely eliminate avian predators from the study area, fish releases conducted after deployment of deterrent devices experienced only minor predation.

In addition to avian predation, juvenile Chinook smolts released on 11 March experienced mortality caused by poor water quality conditions in the post-passage holding tanks. The poor water quality was likely caused by maintenance being conducted on the adult fish ladder by the Oregon Department of Fish and Wildlife. These maintenance activities caused a reduction in water quality to one of the sources supplying water to the post-passage holding tanks. This reduction in water quality resulted in the mortality of fish previously released that were being held to assess 48-hr survival.

The overall mortality rates of both treatment and control fish observed on these two days (4 March and 11 March) were considerably higher than for fish released during all other days. Consequently, data collected on these days could not be pooled with data from the remaining release days, and were therefore removed from the final analytical data set to increase the precision of the survival estimates.

Over the course of the study, several test fish became entrapped along the rip-rap shoreline or under the NFB outfall chute. In all cases, the locations of these fish were known, but were impossible to recapture. In a few incidences, the fish were recaptured several hours following entrapment, but were not used in the analytical sample since the causal mechanisms for any injuries or mortality could not determined.

3.2.2 Test Fish

A total of 1,296 Chinook smolts and 1,118 juvenile steelhead were HI-Z tagged and released to evaluate survival and injury through the NFB and the Link Chute, and an additional 103 steelhead were released to evaluate the Unit 13 Outfall Chute (Table 2). A total of 941 Chinook and 1,182 juvenile steelhead were used in the analytical sample to estimate survival and passage related maladies. Juvenile Chinook not included in the analytical sample included 95 fish released on 4 March (removed as a result of avian predation), and 250 fish released on 11 March (removed as a result of poor water quality conditions in post-passage holding tank), and 10 fish that were replaced due to entrapment; 39 juvenile steelhead were not used and were replaced due to entrapment.

No significant differences were detected in fish length between treatment and control groups for both juvenile Chinook ($df = 939$; $t = -0.14$; $P = 0.8901$) and steelhead ($df = 1180$; $t = -1.63$; $P = 0.1043$). Overall, juvenile Chinook smolts were smaller than steelhead with a mean length of 153 mm and ranging from 117 mm to 215 mm TL. The mean length for juvenile steelhead was 193 mm TL and ranged from 147 mm to 249 mm (Figure 12).

3.2.3 Fish Recapture Rates and Times

Recapture rates for all test scenarios were high; with rates of greater than or equal to 99% for all but one scenario (steelhead released through the Link Chute at 400cfs had a recapture rate of 98.8%; Table 3). All except three juvenile Chinook and three steelhead released into the Link Chute were recaptured and all except one fish of each species released in the NFB was physically recaptured. All Chinook released as control fish were recaptured, and all but one steelhead (control fish) were also recaptured.

Median recapture time was similar among all release locations and test species. The median recapture time for all treatment groups of juvenile Chinook was approximately 6 minutes, with times ranging from about 1 minute to approximately 18 minutes (Table 4). The median retrieval time for juvenile Chinook salmon released at the control site was 5 minutes, with times ranging from about 2 minutes to 95 minutes. The median recapture time for all treatment release groups of steelhead was approximately 5 minutes, with times ranging from 1 minute to 165 minutes (Table 4). The median recapture time for steelhead released as controls was 4 min, with times ranging from about 1 minute to approximately 25 minutes.

3.2.4 Survival Probabilities

Chi-square tests indicated homogeneity ($P>0.05$) with respect to frequency of alive and dead fish between daily controls trials allowing for the pooling of the analytical data. Homogeneity ($P>0.05$) in frequency of fish alive and dead was also revealed between trials of each treatment group. Thus, survival for each treatment was estimated relative to survival of the pooled control trials (Normandeau Associates and Skalski 2005). Likelihood ratio test indicated no significant difference (P>0.05) between the simplified (H_0: $P_A = P_D$) and generalized (H_A:$P_A \neq P_D$) models. Therefore, the simplified (reduced) model was most appropriate and was used in all subsequent analyses of survival and its associated standard error.

The statistical criteria set forth for the experiment and the primary objectives of the study (precision level of <±2.5%, 95% of the time) were met for all conditions tested with steelhead. Although the 1 hr survival estimates for juvenile Chinook met the primary statistical goals, the 48 hr survival estimates for Chinook were slightly less precise (±2.8%) than the pre-specified precision level of <±2.5%, 95% of the time. The sample size of Chinook would have been sufficient to meet the pre-specified precision levels had the analytical sample not been reduced by the necessity to remove the Chinook released on 4 and 11 March from the analytical data set.

3.2.4.1 North Fish Bypass

Chinook Salmon

Immediate (1 hr) and latent (48 hr) direct survival probabilities were 100% for juvenile Chinook released through the NFB at all discharge rates tested (Table 5 and Appendix B). While the 1 hr and 48 hr survival point estimates were identical, the variation associated with each estimate increased slightly for the 48 hour estimates. At a flow of 400 cfs through the NFB, juvenile Chinook had a 95% confidence interval (CI) ranging from 98.8% to 100% for the immediate (1 hr) survival and 97.3% to 100% for the latent (48 hr) survival. At a flow of 250 cfs through the NFB, the 95% CI around the immediate (1hr) survival estimate for juvenile Chinook ranged from 98.3% to 100% and ranged from 97.2% to 100% for the latent (48 hr) survival estimate.

Steelhead

Immediate (1 hr) and latent (48 hr) direct survival probabilities were greater than 99% for juvenile steelhead released through the NFB at all discharge rates tested (Table 5), and were nearly identical to those reported for juvenile Chinook. None of the steelhead released through the NFB at either discharge rate were recaptured dead; however one fish released at the 250 cfs test died during the 48 hr holding period, resulting in a slightly lower latent survival estimate for that scenario. The immediate (1 hr) and latent (48 hr) survival rates for steelhead released through the NFB at 400 cfs were both 100% (1.000, 95% CI = 0.989 to 1.000). Similarly, the immediate survival rate for fish released through the NFB at 250 cfs was also 100% (1.000, 95% CI = 0.993 to 1.000), while the latent (48 hr) survival estimate was 99.7% (0.997, 95% CI = 0.98.2 to 1.000).

3.2.4.2 Link Chute

Chinook Salmon

Similar to the survival estimates for the NFB, estimates of immediate (1 hr) and latent (48 hr) direct survival were 100% for juvenile Chinook released through the Link Chute at all discharge rates tested (Table 5). Also similar to the NFB, the variation associated with the 48 hour estimate increased slightly. At a discharge flow of 400 cfs through the NFB, juvenile Chinook passing through the Link Chute had a 95% CI ranging from 98.5% to 100% for the immediate (1 hr) survival and 97.2% to 100% for the latent (48 hr) survival. At a discharge flow of 250 cfs through the NFB, the 95% CI around the immediate survival estimate for juvenile Chinook passing through the Link Chute ranged from 98.3% to 100%, and for the latent (48 hr) survival estimate ranged from 97.2% to 100%.

Steelhead

Point estimates of immediate (1 hr) and latent (48 hr) direct survival were slightly lower for steelhead passing through the Link Chute than for Chinook, however all estimates were greater than 98% (Table 5). Two juvenile steelhead released into the Link Chute with 400 cfs passing through the NFB were not recaptured and were therefore assigned dead resulting in an immediate survival probability of 99.6% (0.996, 95% CI = 0.983 to 1.000). Three additional steelhead died during the 48 hr holding period resulting in a latent survival probability of 98.4% (0.984, 95% CI = 0.965 to 1.000). Only one steelhead was recapture dead following passage through the Link Chute with 250 cfs passing through the NFB resulting in an immediate (1 hr) and latent (48 hr) survival probability of 99.7% (0.997, 95% CI = 0.982 to 1.000).

3.2.4.3 Unit 13 Outfall Chute

Steelhead

None of the juvenile steelhead released through the Unit 13 Outfall Chute were recovered dead or died during the 48 hr holding period. As a result, the immediate (1 hr) and latent (48 hr) survival rates estimated for this route were 100% (1.000, 95% CI = 0.993 to 1.000; Table 5).

3.2.5 Malady Rates

3.2.5.1 North Fish Bypass

Chinook Salmon

Malady rates for juvenile Chinook passing through the NFB were less than 0.5% at all discharge rates tested (Table 6 and Appendix B). One of the 199 recaptured juvenile Chinook that passed through the NFB at 400 cfs was reported as having a malady, which was classified as major. This resulted in an identical combined (all fish with major and minor maladies after adjusting for controls) and major malady only rates of 0.1% (0.001, 95% CI = 0.000 to 0.014). At 250 cfs, the combined malady rate for juvenile Chinook was similar (0.003, 95% CI = 0.000 to 0.018) to the combined malady rate for Chinook at 400 cfs. No Chinook had maladies classified as major following passage at 250 cfs (0.000, 95% CI = 0.000 to 0.008).

Steelhead

Similar to Chinook, malady rates for steelhead passing through the NFB were less than 0.5% for all discharge rates tests (Table 6). Only one fish released at 400 cfs was recaptured with a passage related malady resulting in a combined malady rate of 0.03% (0.0003, 95% CI = 0.000 to 0.011). No other maladies occurred for steelhead passing through the NFB.

3.2.5.2 Link Chute

Chinook

Malady rates for Chinook passing through the Link Chute were less than 0.5% at all NFB discharge rates tested (Table 6). One Chinook was recaptured with a minor malady following passage through the Link Chute with the NFB operating at 400 cfs resulting in a combined malady rate of 0.1% (0.001, 95% CI = 0.000 to 0.014). No other maladies were reported for Chinook passing through the Link Chute.

Steelhead

Malady rates for steelhead passing through the Link Chute varied between NFB discharge flows (Table 6). Overall, malady rates for steelhead passing through the Link Chute while the NFB was operating at 400 cfs were less than 0.5% and similar to those reported for Chinook. However, with 250 cfs passing through the NFB, the combined malady rate was calculated to be 1.6% (0.016, 95% CI = 0.000 to 0.038), although the confidence intervals surrounding this estimate were comparatively wide. When fish with only major maladies were considered, the malady rate for steelhead passing at 250 cfs decreased by more than half (0.007, 95% CI = 0.000 to 0.020).

3.2.5.3 Unit 13 Outfall Chute

Steelhead

One of the 103 juvenile steelhead released through the Unit 13 Outfall Chute was recaptured with a minor malady (Table 6). This resulted in a combined malady rate of 0.6% (0.006, 95% CI = 0.000 to 0.033). No major maladies were reported for steelhead passing through the Unit 13 Outfall Chute.

3.2.6 Injury Type and Probable Cause

Overall, there were 11 passage related maladies observed during this study; four reported for Chinook and seven reported for steelhead. These maladies included physical injury (operculum damage, external scrapes and bruises, and internal hemorrhaging), and loss of equilibrium (Figure 13 and Appendix C). Some fish had multiple maladies, although the dominant malady type varied between species.

In general, maladies to juvenile Chinook were largely characterized by internal hemorrhaging (n = 2) and loss of equilibrium (n = 1), wherein the source of the injury was unknown. One Chinook released through the NFB was observed to have a minor bruising behind the head which appeared to be cause by mechanical forces. In contrast, maladies to juvenile steelhead were more consistent with physical injury associated with external damage to the head and operculum. Of the seven steelhead recaptured with a physical injury, over half (n = 4) were from fish that passed through the Link Chute and were characterized as having been caused by mechanical forces. Physical injuries reported for steelhead passing through the NFB (n = 1) and Unit 13 Outfall Chute (n = 1) were characterized as damage to the operculum, and appeared to be caused by shear related forces.

Physical injuries were observed on two control fish; one Chinook and one steelhead. Necropsy of the Chinook which died during the 48 hr holding period revealed the fish had slight internal hemorrhaging, although the cause of the injury could not be determined. The steelhead was recovered with minor bruising along the head, which appeared to be caused by mechanical forces although the exact source of the injury was not determined.

3.3 Mark Recapture Evaluation (Objective 3)

3.3.1 Overview

Assessing fish condition and survival following passage through the inner forebay and Reach-One of the Unit 13 Bypass began on 18 March and was completed on 23 March. A total of 629 hatchery reared Chinook salmon (515 treatment and 114 control) and 479 steelhead smolts (349 treatment and 130 control) were marked and released (Table 7).

Juvenile Chinook were generally smaller than steelhead, with a fork length averaging 146 mm, and ranging from 99 mm to 205 mm (Table 7). Steelhead averaged 186 mm and ranged from 106 to 244 mm in length. No significant differences were detected in fish length between treatment and control groups for both juvenile Chinook (df = 627; t = 0.86; P = 0.3916) and steelhead (df = 477; t = 0.36; P = 0.7198).

3.3.2 Survival and Malady Estimates

A total of 246 marked Chinook smolts and 89 juvenile steelhead were recaptured and examined following passage through the inner forebay and Reach-One of the Unit 13 bypass (Table 7). Fish were collected over a three day period after being released. Most of the Chinook (96%) and steelhead (82%) were recaptured during the first two days of sampling. Only one of the Chinook smolts recaptured and held, died during the holding period resulting in a latent (48 hr) survival estimate of 99.6%. No steelhead were recovered dead or died during the 48 hour holding period, resulting in a survival estimate of 100%.

The combined malady rate was slightly higher for Chinook smolts than for juvenile steelhead, although for both species was less than 4% (Table 7). Of the 246 Chinook smolts that were recaptured and examined, only seven were reported having a passage related malady classified as either minor or major. This resulted in a combined malady rate of 3.3%. When Chinook with only major injuries were considered, the malady rate decreased by more than half and was 1.6%. The combined malady rate for juvenile steelhead was 1.4%, which was based on only two fish recovered with maladies. When steelhead with only major maladies were considered (n = 1), the malady rate decreased to 1.1%.

One injury was noted for a juvenile steelhead released as a control fish, and the estimated malady rate presented above was adjusted accordingly.

3.3.3 Malady Type and Probable Cause

Maladies observed during this assessment included descaling, external scrapes and bruises and hemorrhaging on the fins (Figure 14 and Appendix D). Some fish had multiple injuries. The dominant injury type varied between species.

The dominant malady type for juvenile Chinook passing through the inner forebay and Reach-One was descaling. All except one injured juvenile Chinook had some degree of descaling. The descaling sustained by these fish appeared to be largely attributed to mechanical contact or abrasion with a solid object. The only injured fish that was not descaled had a slight hemorrhage along the caudal fin. The one Chinook smolt that died during this study was recovered with elongated bruising and descaling on either side of its body just forward of the dorsal fin. Based on the appearance and location, the bruising appeared to be associated with a mechanical "pinch".

The maladies observed on the two injured steelhead appeared to be related to mechanical forces. In both cases, the physical injuries were characterized as bruising between the dorsal fin and head, and appeared to be largely attributed to physical contact or abrasion with a solid object. In addition to bruising, one fish also had two large abrasions along either side of the body between the head and dorsal fin. One of the steelhead designated as a control fish was also recovered injured, which was characterized as minor descaling along both sides of the body.

4.0 DISCUSSION

The primary objectives of this study were met. Estimates of survival and condition were obtained for juvenile Chinook salmon and steelhead following passage through the newly constructed NFB and modified Unit 13 bypass at the T.W. Sullivan Hydroelectric Project. Estimates of direct survival and injury for passage through the NFB and Link Chute (Unit 13 Bypass Reach-Two) were derived using the HI-Z tag technology. Similar metrics were derived for fish passing through the inner forebay and upper portion of the Unit 13 bypass (Reach-One) using mark-recapture techniques on fish of known condition.

Initial releases of HI-Z tagged fish were conducted at a NFB flow of 400 cfs. However, in an effort to gain further information regarding the effects of a lower discharge rate on fish passage and condition, additional fish were released with 250 cfs passing through the NFB. In addition to the lower discharge through the NFB, the modified Unit 13 Outfall Chute was also evaluated for fish passage survival and condition using juvenile steelhead.

The results of the HI-Z tag evaluation indicate that the NFB and Link Chute are benign passage routes for juvenile Chinook and steelhead under the test conditions evaluated. Direct survival estimates (1 hr and 48 hr) were in excess of 98% regardless of passage route, discharge rate, or fish species. These estimates were likely conservative as some of the fish considered as mortalities in the survival estimate were not recaptured dead, but rather were assumed to be dead based on radio telemetry data. Assuming that unrecovered fish are dead is a conservative approach to estimating survival as it is possible that the radio tag was knocked off and the fish escaped alive, or that the fish sought refuge and became physically trapped along the river bottom and did not surface.

To improve the statistical precision of survival and malady estimates generated by the HI-Z tag evaluation, two sampling days were removed from the analytical sample. These days were not representative of passage conditions observed during the evaluation as intense avian predation and reduced water quality conditions in the post-passage holding tanks contributed to disproportionately high rates of non-passage related mortality for juvenile Chinook. While the rate of non-passage related mortality during these two days was similar between control and treatment groups, overall these rates were disproportionately higher than the rates observed during the remaining days of the evaluation. Consequently, these data could not be pooled with remaining data collected during the evaluation. While removing these release trials reduced the total number of fish in the analytical sample, having the capability to pool the control fish releases across treatment groups ultimately improved the overall statistical precision of the survival and malady estimates.

Overall, malady rates of juvenile salmonids passing through the NFB and Link Chute were minimal. The highest combined malady rate was 1.6 %, which was calculated for steelhead passing through the Link Chute at the lower NFB flow of 250 cfs; all other malady estimates were less than 1 %. Of the few maladies observed that were associated with passing through the Link Chute, most appeared to be caused by mechanical forces (*e.g.,* external scrapes and bruises) particularly for steelhead. The most likely causative mechanism was contact or abrasion on the floor or walls of the NFB as fish exited the Link Chute. Maladies associated with passage through the NFB and Unit 13 Outfall Chute were more consistent with water shear or sudden changes in water velocity (*e.g.*, torn operculum). However these apparent differences are likely only generalizations since overall the numbers of maladies observed were low.

The modified Unit 13 Outfall Chute also appeared to be a benign passage route for steelhead under the hydraulic conditions tested. During the evaluation of the outfall chute, the tailrace elevation was relatively low at approximately 10 ft MSL. At this tailwater elevation the vertical drop distance from the end of the chute was approximately 14ft; a distance near the maximum possible height differential of approximately 15 ft and what could be considered a worst case scenario for fish passing through the modified outfall chute.

While each hydroelectric project is unique and has a variety of characteristics that make it difficult to compare results between projects, non-turbine passage routes have been typically shown to be more benign to downstream migrating smolts than passage through turbines (Muir *et al.* 2001, Bickford and Skalski 2000). Survival estimates based on HI-Z tag methodologies for fish passing through non-turbine routes (*i.e*., spillways, sluiceways, and fish bypass outfalls) on the mainstem of the Snake and Columbia Rivers have ranged from 80% – 100% (Appendix E). The magnitude of injury and mortality associated with non-turbine passage has been shown to be related to several characteristics of the passage route including (but not limited to), the volume of water passing through a structure, the vertical location of the outfall spill (*i.e.,* skimming or plunging flow), the presence (or absence) of obstructions in the flow path, and (in very few cases) the species of fish being tested (Heisey *et al.* 2008). Passage through non-turbine routes can subject entrained fish to varying hydraulic forces, including potential collisions with rocks or other objects, abrasive surfaces, obstructions in the flow path, or contact with flow control gates (Bell *et al.* 1972; Ruggles and Murray 1983; Heisey *et al.* 1996). Therefore, fish survival and malady rates vary depending upon the magnitude of the influence of these factors at each site, the location of the fish within a discharge jet (Normandeau and Skalski 2006; and Normandeau Associates 2006) and also the orientation and trajectory of fish entering the downstream waters (Groves 1972). Generally fish traveling deeper within a discharge jet have a greater chance of being injured because of their proximity to structural features of the passage route. Based on the results of the HI-Z evaluation, the hydraulic and structural characteristics of the NFB and Link Chute appear to be conducive to safe fish passage at the flow rates tested.

The results of the mark-recapture evaluation indicated that survival following passage through the inner forebay and upper portion of the Unit 13 Bypass (Reach-One) was in excess of 99.5% for both species. In fact, only one juvenile Chinook died during this evaluation, and none of the steelhead that were recaptured, were recaptured dead or died during the holding period. These estimates of survival were slightly higher than those recently reported for Chinook (97.4%), but were consistent with those reported for steelhead (99.6%) in 2007 when run-of-the-river fish were randomly selected and held for 48 hours (Karchesky *et al*. 2007a).

Malady rates of juvenile salmonids that were recaptured following passage through the inner forebay and Reach-One were also minimal. Juvenile Chinook had the highest combined malady rate of 3%, which decreased by more than half when only major maladies were considered. Malady rates for steelhead were all less than 1.5%. These rates were considerably lower than those estimated in 2007 (Karchesky *et. al* 2007a), which indicated a combined malady rate (physical injury and descaling) of nearly 40% for Chinook and 42% for steelhead. This large difference in malady rates may be attributed to releasing fish of known condition and removing maladies occurring upstream of the Project from the sample. However, hydraulic changes that improved flow conditions along the inner forebay between study years may also explain the lower malady rates. Modification to the inner forebay in early 2008 reduced the large hydraulic vortices, which had formed along the inner intake screens, and were thought to negatively affect passage efficiency and possibly fish condition (Karchesky *et al.* 2007a).

Recapture rates of marked fish released to assess Reach-One were expectedly low. Marked fish were released at the head of the trash racks leading into the inner forebay rather than directly into the entrance of the Unit 13 Bypass. This approach was more consistent with previous evaluations using run-of-the-river fish which passed through the inner forebay before being captured and evaluated. Releasing fish near the trash racks also allowed the use of fish of known condition to assess recent modifications to the inner forebay. However, by not directly releasing fish in the Unit 13 Bypass, the likelihood of recapturing tagged fish was reduced. Approximately 48% of the Chinook originally released were recaptured and assessed, and even fewer steelhead (26%) were recaptured. Juvenile salmonids, particularly steelhead, have been shown to hold in the approach channel of the NFB when only the Unit 13 bypass is operating (Karchesky *et al.* 2007a). Following the three day recapture period and immediately prior to the NFB being reopened, several hundred juvenile salmonids were seen swimming near the surface immediately upstream of the NFB isolation gate. Some of these fish were likely marked and subsequently passed through the NFB. Since low recapture rates were anticipated, the total number of marked fish released was adjusted so that the number of fish ultimately examined was similar to those examined in previous studies (PGE 1998; Karchesky *et al.* 2007a).

While modifications to existing bypasses or newly constructed bypasses are typically designed to meet federal criteria standards for safe fish passage (NMFS 2008), it is important to conduct a post-construction verification study to evaluate fish injury and mortality. Juvenile salmonids equipped with HI-Z tags have experienced injuries rates of nearly 25% following passage through a newly constructed bypass facility (Normandeau 2006c). However, the high survival rates and the few maladies observed during the HI-Z tag and mark-recapture evaluations indicate that the newly constructed NFB and modified Unit 13 bypass are safe conveyances for fish passage under the environmental conditions tested during these evaluations.

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Exhibit D

TABLES

Exhibit D

Table 1.

Condition codes assigned to fish during passage survival and injury evaluation at the T.W. Sullivan Powerhouse, Willamette River, Oregon.

Status Code	Description
*	Turbine/passage-related malady
4	Damaged gill(s): hemorrhaged, torn or inverted
5	Major scale loss, >50% Scaled
6	Severed body or nearly severed
7	Decapitated or nearly decapitated
8	Damaged eye(s): hemorrhaged, bulged, ruptured or missing
9	Damaged operculum: torn, bent
A	No visible marks on fish
B	Flesh tear at tag site(s)
C	Minor scale loss, <50%
E	Laceration(s): tear(s) on body or head (not severed)
F	Torn isthmus
G	Hemorrhaged, bruised head or body
H	LOE
K	Failed to enter system
L	Fish likely preyed on (telemetry, circumstances relative to recapture)
M	Substantial bleeding at tag site
P	Predator marks
Q	Other information
R	Replaced due to unrecoverable conditions
T	Trapped inside tunnel/gate well
V	Fins displaced, or hemorrhaged (ripped, torn, or pulled) from origin
W	Abrasion / Scrape

Dissection Codes

Code	Description
1	Shear
2	Mechanical
3	Pressure
4	Undetermined
5	Mechanical/Shear
6	Mechanical/Pressure
7	Shear/Pressure
B	Swim bladder ruptured or expanded
D	Kidneys damaged (hemorrhaged)
E	Broken bones obvious

Code	Description
F	Hemorrhaged internally
J	Major
L	Organ displacement
M	Minor
N	Heart damage, rupture, hemorrhaged
O	Liver damage, rupture, hemorrhaged.
R	Necropsied, no obvious injuries
S	Necropsied, internal injuries observed
W	Head removed; i.e. otolith

Exhibit D

Table 2.

Daily release schedule for juvenile Chinook salmon and steelhead released through the NFB, Link Chute, and Unit 13 Outfall Chute with controls released into the tailrace of the T.W. Sullivan Powerhouse, spring 2008.

	Chinook					Steelhead							
	NFB		Link Chute			NFB		Link Chute					
Date	**400cfs**	**250cfs**	**400cfs**	**250cfs**	**Control**	**400cfs**	**250cfs**	**400cfs**	**250cfs**	**Unit 13 Outfall Chute**	**Control**	**Analytical sample[a]**	**Total fish released[b]**
3-Mar	40		10		29							**79**	***80***
4-Mar	10		50		23							**-**	***95***
5-Mar	80		79		57							**216**	***221***
6-Mar	79		110		59							**248**	***250***
7-Mar						89		96			52	**237**	***260***
8-Mar						83		77			72	**232**	***240***
9-Mar		100		100	59							**259**	***260***
10-Mar							100		102		60	**262**	***268***
11-Mar	49	50	50	49	49							**-**	***250***
12-Mar						49	50	50	50		50	**249**	***250***
13-Mar						30		29		103	40	**202**	***203***
14-Mar		50		49	40							**139**	***140***
Total	***258***	***200***	***299***	***198***	***316***	***251***	***150***	***252***	***152***	***103***	***274***	**2123**	***2517***

[a] Analytical sample does not include fish released on 4 March or 11 March nor those that were replaced.

[b] Total fish released includes all fish released.

Exhibit D

Table 3.

Recapture rates for juvenile Chinook salmon and steelhead released through the NFB, Link Chute, and Unit 13 Outfall Chute with controls released into the tailrace of the T.W. Sullivan Powerhouse, spring 2008.

	Chinook					Steelhead					
	NFB		Link Chute			NFB		Link Chute		Unit 13 Outfall Chute	
	400 cfs	250 cfs	400 cfs	250 cfs	Control	400 cfs	250 cfs	400 cfs	250 cfs		Control
Number released	199	150	199	149	244	251	150	252	152	103	274
Recovered alive	199	149	197	148	242	250	150	249	151	103	273
Recovered dead	0	0	0	0	2	0	0	0	1	0	0
Not recovered	0	1	2	1	0	1	0	3	0	0	1
Recapture rate	1.00	0.99	0.99	0.99	1.00	1.00	1.00	0.99	1.00	1.00	1.00

Exhibit D

Table 4.

Summary of recapture times[a] for juvenile Chinook and steelhead released through the NFB, Link Chute, and Unit 13 Outfall Chute with controls released into the tailrace of the T.W. Sullivan Powerhouse, spring 2008. Times are shown in minutes.

	Chinook					Steelhead					
	NFB		Link Chute			NFB		Link Chute		Unit 13 Outfall Chute	
	400 cfs	250 cfs	400 cfs	250 cfs	Control	400 cfs	250 cfs	400 cfs	250 cfs		Control
Minimum	2	1	2	2	2	2	2	1	2	1	1
25th Quartile	5	5	4	5	4	3	4	4	4	3	3
Median	**6**	**6**	**5**	**6**	**5**	**4**	**5**	**5**	**5**	**4**	**4**
75th Quartile	7	7	6	7	6	5	6	6	6	6	5
Maximum	16	18	15	11	95	154	59	54	133	165	25

[a] Recapture time defined as the time between when a fish was released to when it was recaptured downstream.

Table 5.

Status of released juvenile Chinook and steelhead along with estimates of immediate (1 hr) and latent (48 hr) direct survival and 95% confidence intervals released through the T.W. Sullivan fish bypass, spring 2008.

	Chinook					Steelhead					
	NFB		Link Chute			NFB		Link Chute			
	400 cfs	250 cfs	400 cfs	250 cfs	Control	400 cfs	250 cfs	400 cfs	250 cfs	Old Outfall Chute	Control
Number released	199	150	199	149	244	251	150	252	152	103	274
Alive after 48hrs	196	148	195	147	238	250	149	247	151	103	273
Recovered dead or died within 1 hr	0	0	0	0	2	0	0	0	1	0	0
Died between 1hr and 48 hrs	3	1	3	1	4	0	1	3	0	0	0
Assigned dead	0	1	1	1	0	1	0	2	0	0	1
Undetermined	0	0	1	0	0	0	0	1	0	0	0
Direct (1h) survival rate[a]	1.000	1.000	1.000	1.000		1.000	1.000	0.996	0.997	1.000	
95% confidence interval (±)	0.012	0.017	0.015	0.017		0.011	0.007	0.013	0.015	0.007	
Direct (48h) survival rate[b]	1.000	1.000	1.000	1.000		1.000	0.997	0.984	0.997	1.000	
95% confidence interval (±)	0.027	0.028	0.028	0.028		0.011	0.015	0.019	0.015	0.007	

[a] Considers all fish alive after 1 hour and is adjusted for control fish survival.

[b] Considers all fish alive after 48 hours and is adjusted for control fish survival.

Exhibit D

Table 6.

Estimated malady rates and 95% confidence intervals for juvenile Chinook and steelhead released through the T.W. Sullivan fish bypass, spring 2008.

	Chinook NFB 400cfs	Chinook NFB 250cfs	Chinook Link Chute 400cfs	Chinook Link Chute 250cfs	Chinook Control	Steelhead NFB 400cfs	Steelhead NFB 250cfs	Steelhead Link Chute 400cfs	Steelhead Link Chute 250cfs	Steelhead Unit 13 Outfall Chute	Steelhead Control
Number released	199	150	199	149	244	251	150	252	152	103	274
Number recovered	199	149	197	148	244	250	150	249	152	103	273
Recovered injured	1	1	1	0	1	1	0	1	3	1	1
Minor		*1*	*1*			*1*			*2*	*1*	*1*
Major	*1*				*1*			*1*	*1*		
Combined malady rate	0.001	0.003	0.001	0.000		0.003	0.000	0.004	0.016	0.006	
95% confidence interval (±)	0.013	0.015	0.013	0.008		0.011	0.007	0.008	0.022	0.027	
Major malady only rate	0.001	0.000	0.000	0.000		0.000	0.000	0.004	0.007	0.000	
95% confidence interval (±)	0.013	0.008	0.008	0.008		0.000	0.000	0.008	0.013	0.000	

Table 7.

Summary of mark-recapture evaluation used to assess survival and injury of juvenile Chinook and steelhead following passage through the inner forebay and upper portion of the Unit 13 Bypass (Reach-One) at the T.W. Sullivan Powerhouse, Willamette River, Oregon, spring 2008.

	Chinook		Steelhead	
	Treatment	Control	Treatment	Control
Number released	515	114	349	130
Number collected	246	108	89	118
Number dead (24h)	1	0	0	0
Number dead (48h)	0	0	0	0
Adjusted survival estimate	99.6%		100%	
Number with maladies	8	0	2	1
Minor	4	0	1	0
Major	4	0	1	1
Combined malady rate	0.033		0.014	
Major malady only rate	0.016		0.011	
Average fork length (mm)	145	147	186	187
Min	99	107	110	106
Max	205	191	238	244

Exhibit D

FIGURES

Exhibit D

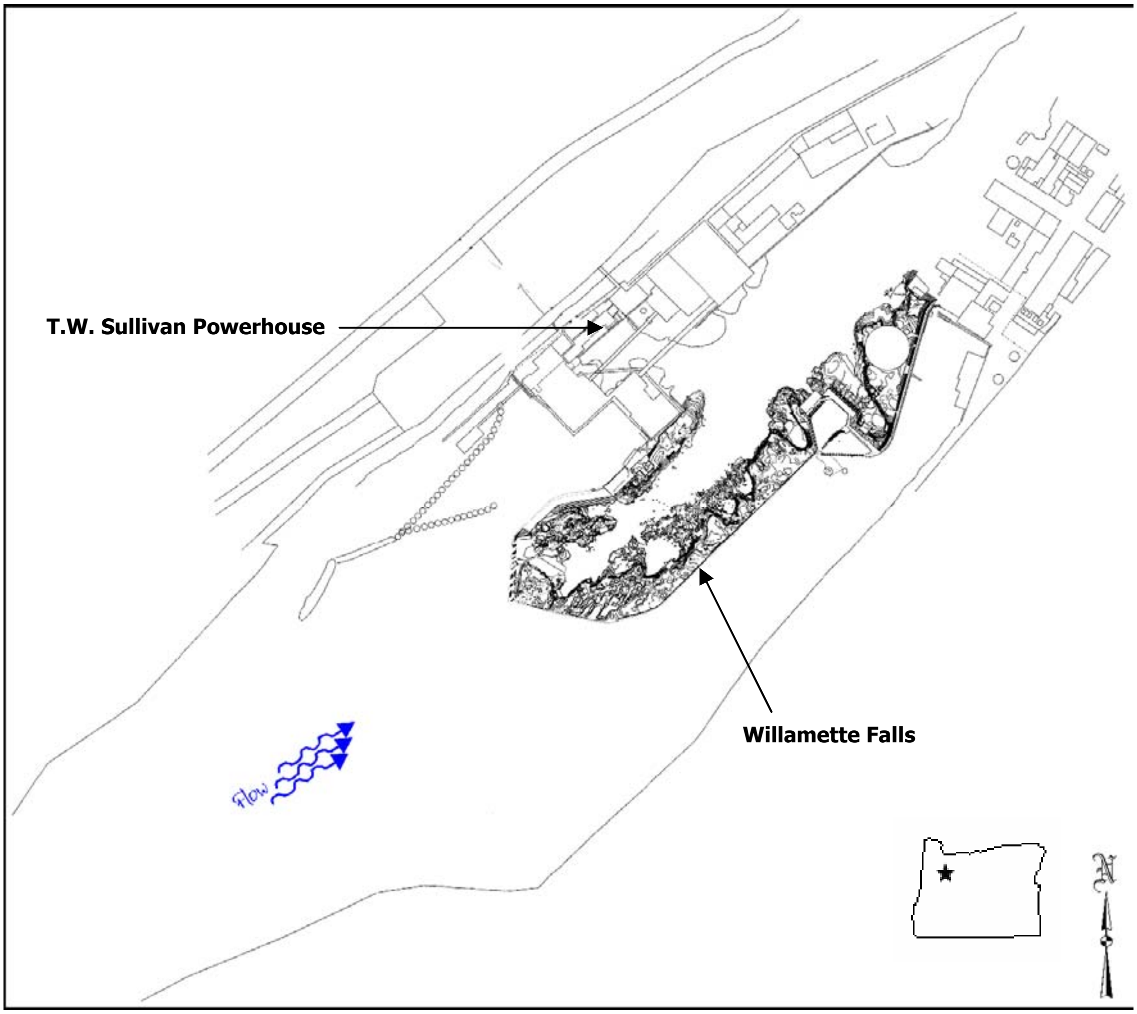


Figure 1.

Generalized layout of the Willamette Falls Project.

Exhibit D

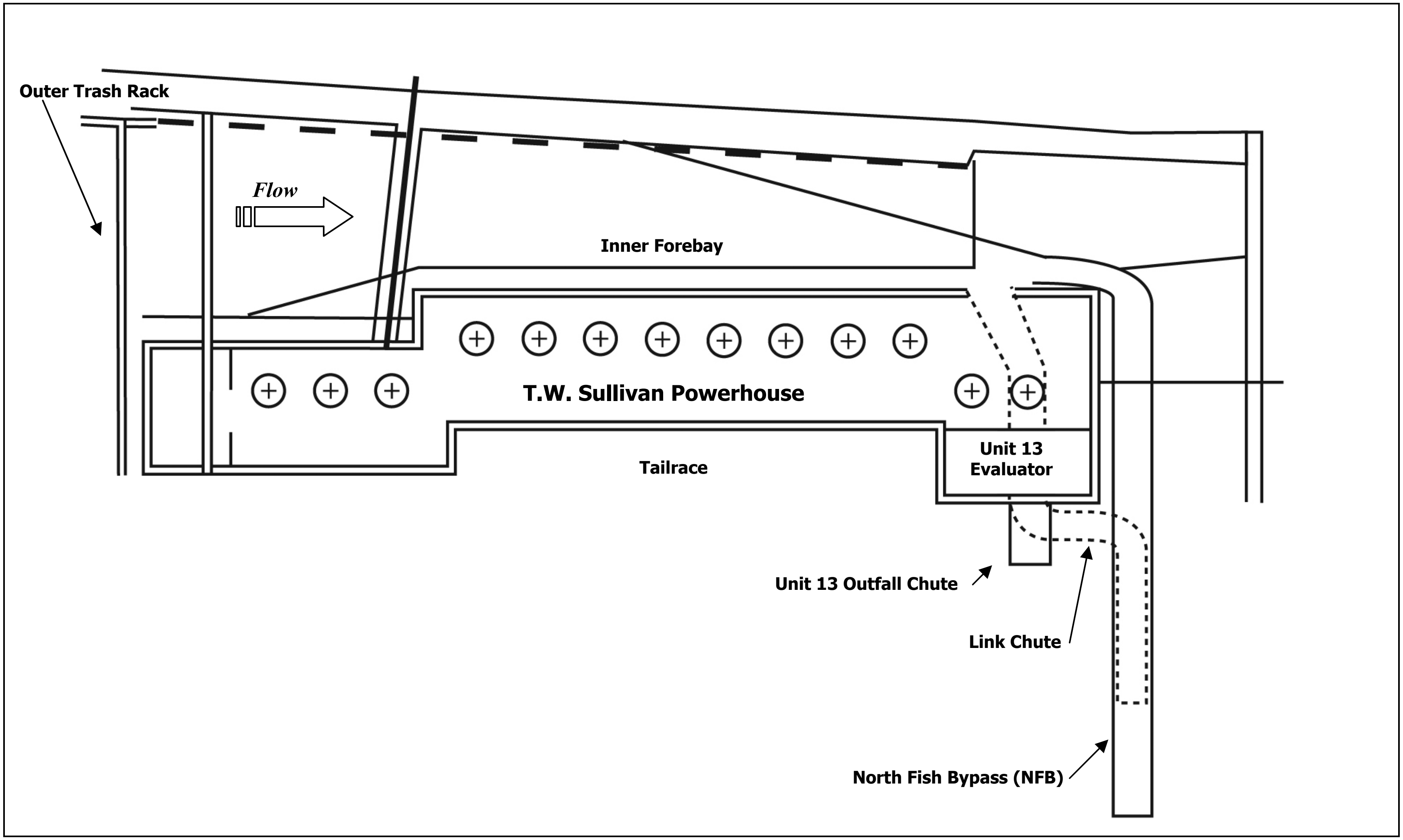
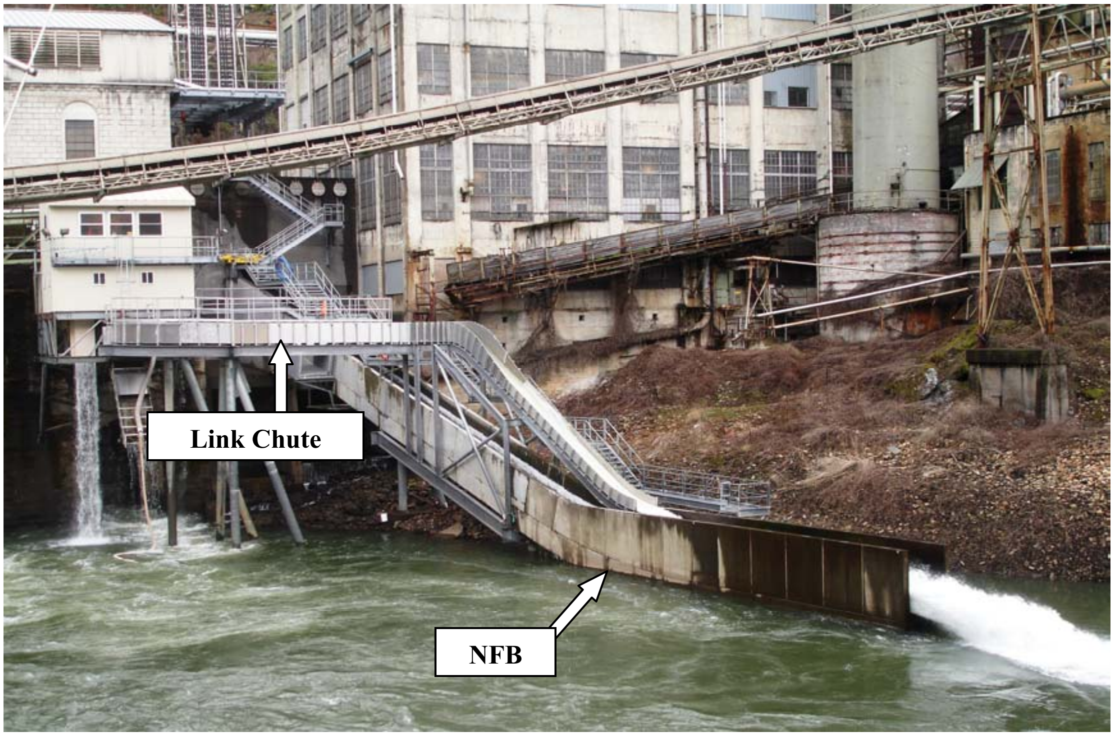


Figure 2.

Detailed schematic of the T.W. Sullivan Powerhouse.



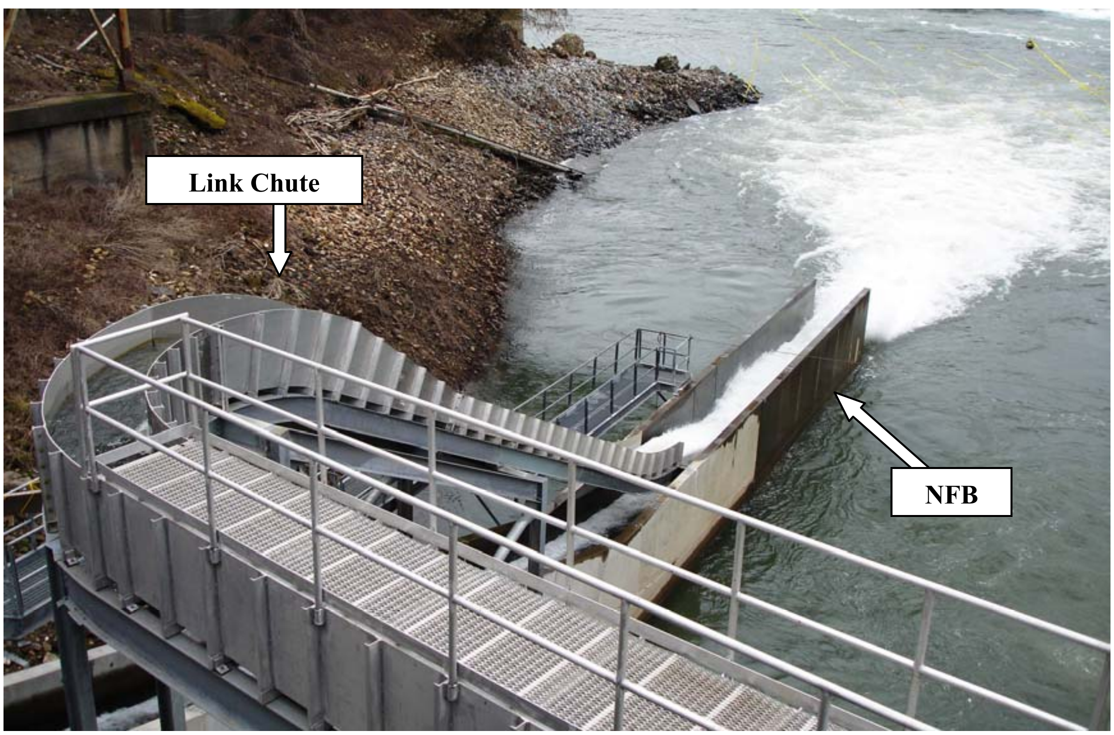


Figure 3.

The newly constructed NFB and Link Chute located adjacent to the T.W. Sullivan Powerhouse, Willamette River, Oregon. The NFB is operating at approximately 400 cfs.

Exhibit D

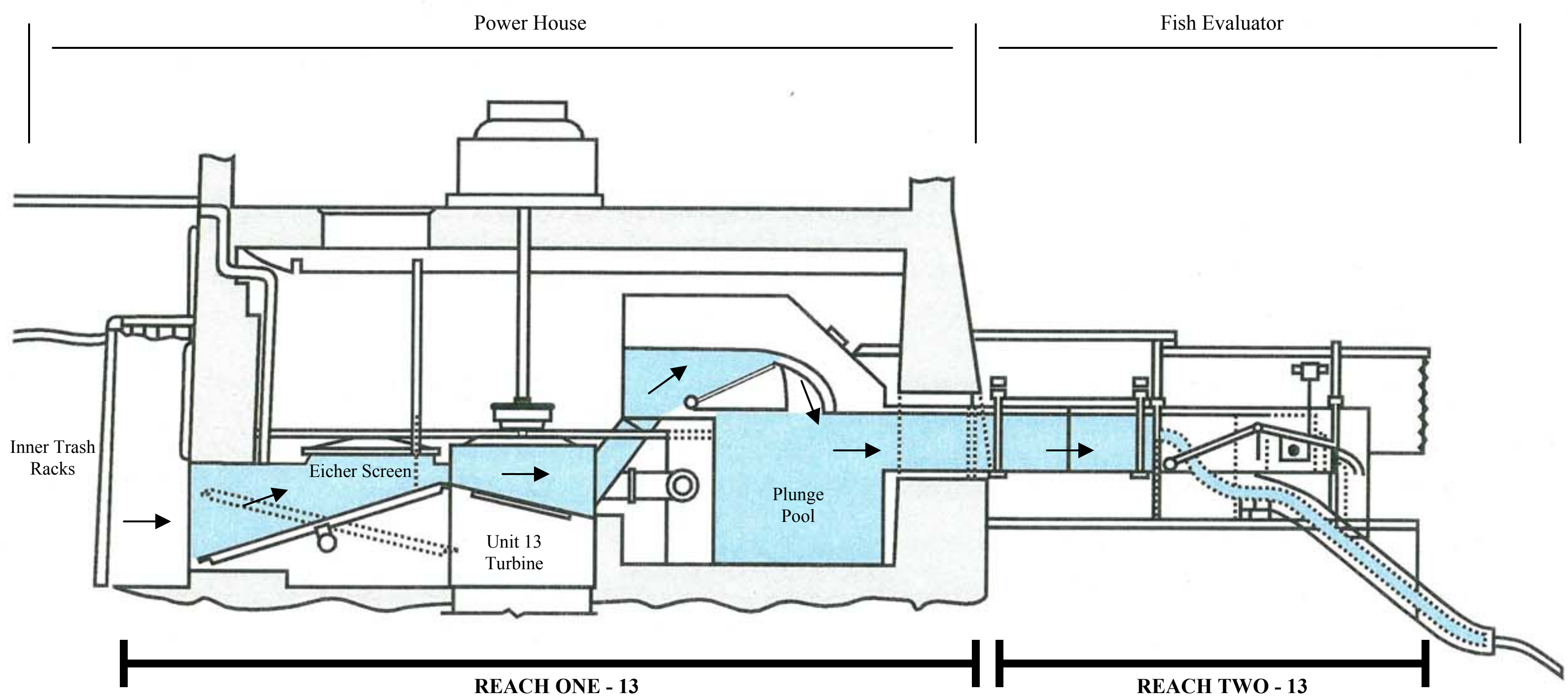


Figure 4.

Cross sectional diagram of the T.W. Sullivan Unit 13 Fish Bypass showing the upper area designated as Reach-One and the lower area designated as Reach-Two. (The Link Chute is also apart of Reach-Two, but is not illustrated here). Arrows indicate fish passage route.

Figure 5. **Juvenile Chinook equipped with two uninflated HI-Z tags and a miniature radio tag.**

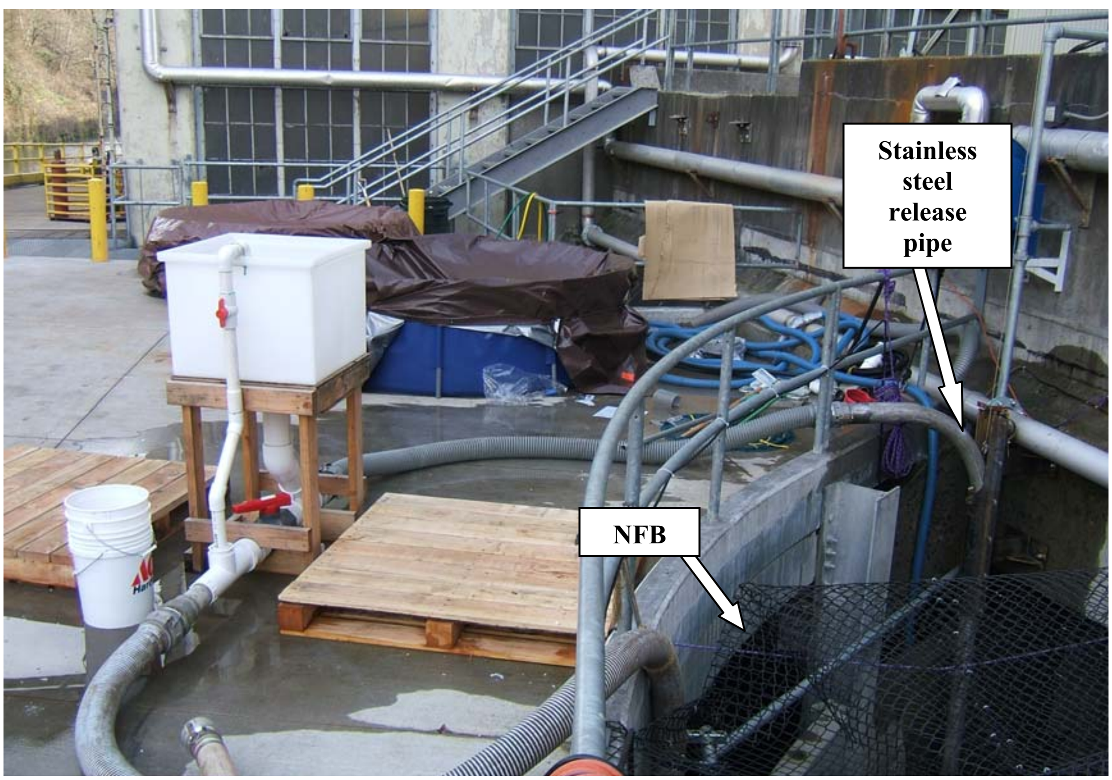


Figure 6. **Induction system located on the upper deck adjacent to the T.W. Sullivan Powerhouse for releasing fish into the NFB.**

Exhibit D

Figure 7. Initial release site for control fish extending along the Unit 13 Outfall Chute into the tailrace.

Figure 8. Relocated release site for control fish located on the opposite of the tailrace from the NFB on the adult fish later.

Figure 9. Fish were manually released into the entrance of the Link Chute just upstream of the selector gate separating the Link Chute and Unit 13 Outfall Chute.

Figure 10. Unit 13 Outfall Chute operating at approximately 30 cfs.

Exhibit D

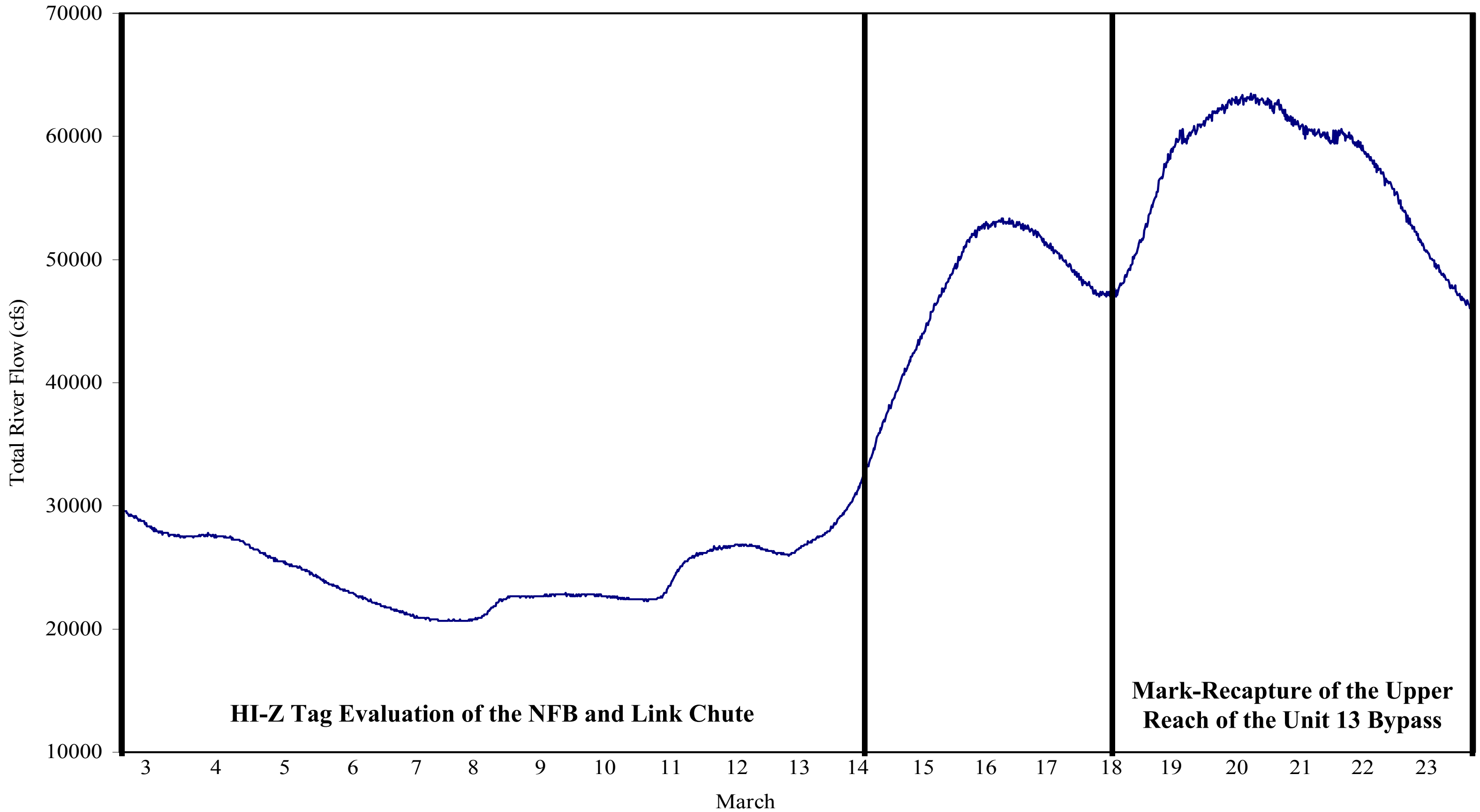
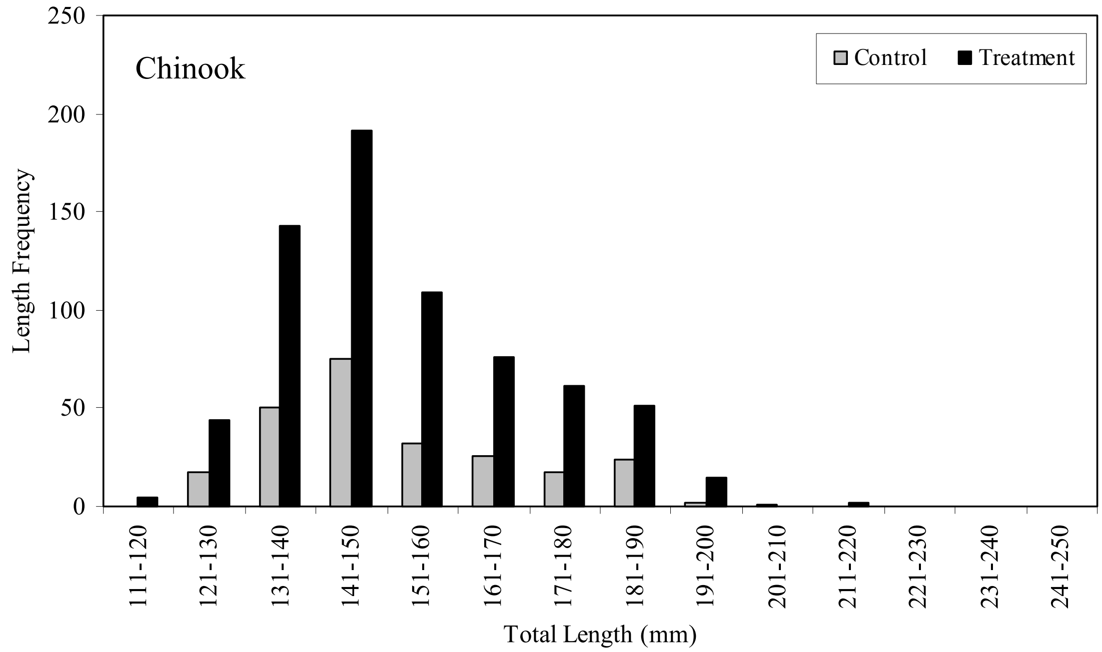


Figure 11.

Average daily river flow recorded at the USGS gauging station located upstream of Willamette Falls and adjusted for accretion during the March evaluation period, spring 2008.



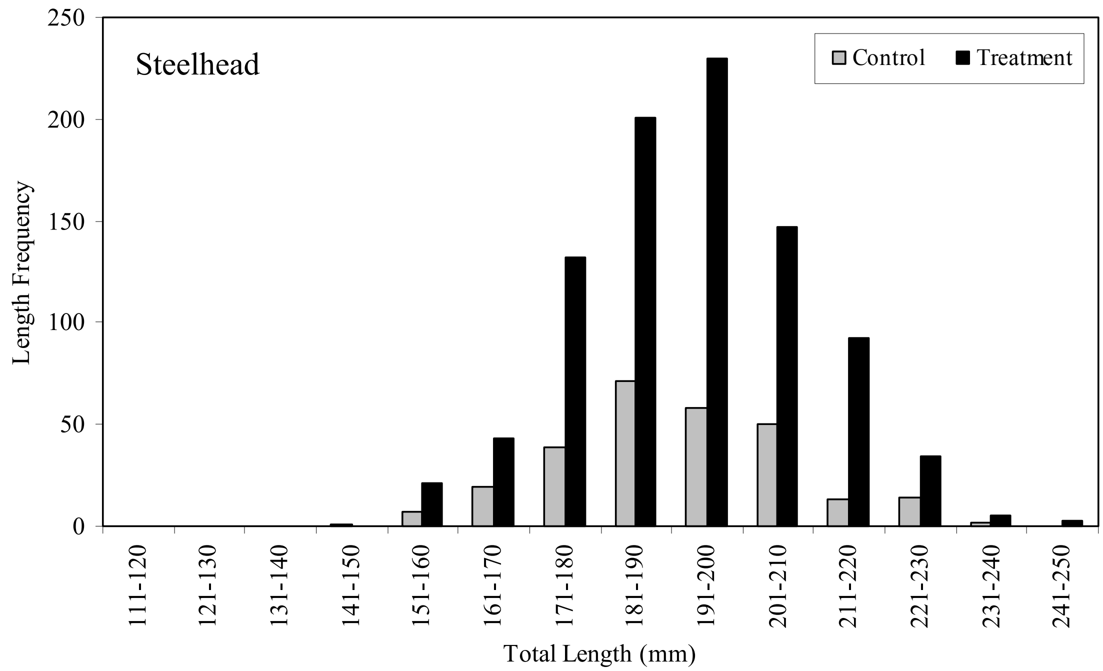
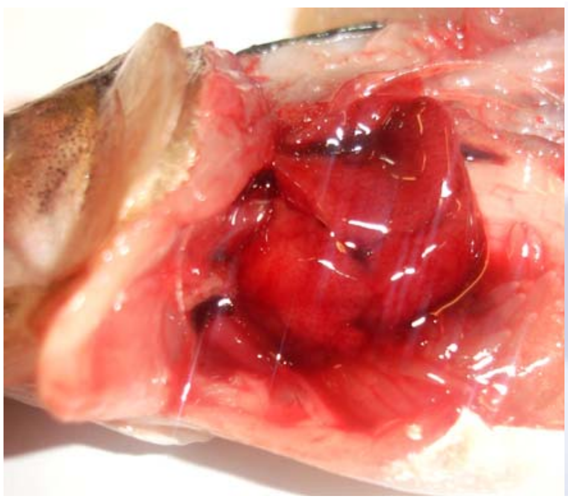
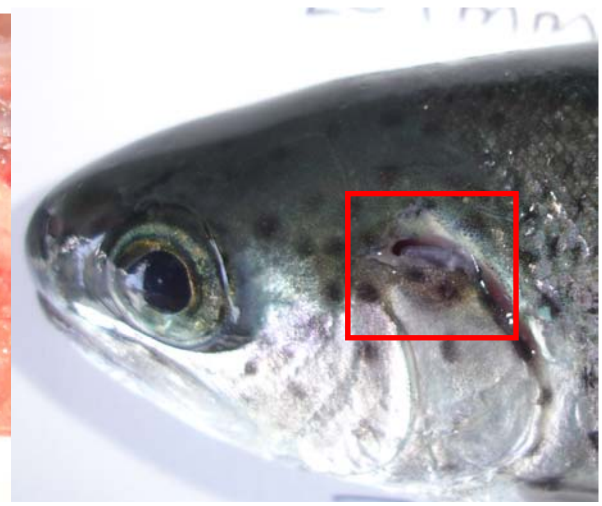


Figure 12.

Length frequency distributions of juvenile Chinook and steelhead released during the HI-Z Tag evaluation at the T.W. Sullivan Powerhouse, spring 2008.

(A) (B)





(C) (D)

Figure 13.

Examples of the dominant injury types observed on test fish during the HI-Z tag evaluation of the NFB, Link Chute, and Unit 13 Outfall Chute at the T.W. Sullivan Powerhouse. Dominate injury types include: (A) avian predation; (B) scrapes and/or bruises along head; (C) internal hemorrhaging; and (D) torn operculum.

(A)

(B)

Figure 14.

Examples of the injuries observed on test fish recollected during the mark-recapture evaluation of the upper reach of the Unit 13 Bypass (Reach-One) at the T.W. Sullivan Powerhouse. Observed injury types include: (A) descaling; and (B) physical abrasion along the side of the body.

Exhibit D

APPENDIX A

DERIVATION OF PRECISION, SAMPLE SIZE, AND MAXIMUM LIKELIHOOD PARAMETERS FOR THE HI'Z TAG EVALUATION AT T.W. SULLIVAN HYDROELECTRIC DEVELOPMENT, WILLAMETTE RIVER, OREGON,

MARCH 2008.

DERIVATION OF PRECISION, SAMPLE SIZE, AND MAXIMUM LIKELIHOOD PARAMETERS

The statistical description below is excerpted from Normandeau Associates and Skalski (2000a). For the sake of brevity, references within the text have been removed. However, interested readers can look up these citations in the report prepared by Normandeau Associates and Skalski (2000a).

The estimation for the likelihood model parameters and sample size requirements discussed in the text are given herein. Additionally, the results of statistical analyses for evaluating homogeneity in recapture and survival probabilities, and in testing hypotheses of equality in parameter estimates under the simplified (H_O:P_A=P_D) versus the most generalized model (H_A:$P_A \neq P_D$) are given.

The following terms are defined for the equations and likelihood functions which follow:

R_C	=	Number of control fish released
R_T	=	Number of treatment fish released
R	=	R_C=R_T
n	=	Number of replicate estimates $\hat{\tau}_i$ (i=1,…,n)
a_C	=	Number of control fish recaptured alive
d_C	=	Number of control fish recaptured dead
a_T	=	Number of treatment fish recaptured alive
d_T	=	Number of treatment fish recaptured dead
S	=	Probability fish survive from the release point of the controls to recapture
P_A	=	Probability an alive fish is recaptured
P_D	=	Probability a dead fish is recaptured
τ	=	Probability a treatment fish survives to the point of the control releases (*i.e.*, passage survival)
1-τ	=	Passage-related mortality.

The precision of the estimate was defined as:

$$P(-\varepsilon < \hat{\tau} - \tau < \varepsilon) = 1 - \alpha$$

or equivalently

$$P(-\varepsilon <| \hat{\tau} - \tau |< \varepsilon) = 1 - \alpha$$

where the absolute errors in estimation, *i.e.*, $|\hat{\tau} - \tau|$, is <ε (1-α) 100% of the time, $\hat{\tau}$ is the estimated passage survival, and ε is the half-width of a (1-α) 100% confidence interval for $\hat{\tau}$ or 1-$\hat{\tau}$. A precision of ±5%, 90% of the time is expressed as P($|\hat{\tau} - \tau|$<0.05)=0.90.

Using the above precision definition and assuming normality of $\hat{\tau} - \tau$, the required total sample size (R) is as follows:

$$P\left(\frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}} < Z < \frac{\varepsilon}{\sqrt{Var(\hat{\tau})}} \right) = 1 - \alpha$$

$$P\left(Z < \frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}}\right) = \alpha / 2$$

$$\Phi\left(\frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}}\right) = \alpha / 2$$

$$\frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}} = Z_{\alpha/2}$$

$$Var(\hat{\tau}) = \frac{\varepsilon^2}{Z^2_{1-\frac{\alpha}{2}}}$$

$$\frac{\tau}{SP_A}\left[\frac{(1-S\tau P_A)}{R_T} + \frac{(1-SP_A)\tau}{R_C}\right] = \frac{\varepsilon^2}{Z^2_{1-\frac{\alpha}{2}}} \ .$$

where Z is a standard normal deviate satisfying the relationship $P(Z>Z_{1-\alpha/2})=\alpha/2$, and Φ is the cumulative distribution function for a standard normal deviate.

If data can be pooled across trials and letting $R_C=R_T=R$, the sample size for each release is

$$R = \frac{\tau}{SP_A}\left[1+\tau-2S\tau P_A\right]\frac{Z^2_{1-\alpha/2}}{\varepsilon^2} \ .$$

By rearranging, this equation can be solved to predetermine the anticipated precision given the available number of fish for a study. In most previous investigations (Normandeau Associates and Skalski 2000a) this equation has been used to calculate sample sizes because of homogeneity between trials; in the present investigation sample size was predetermined using this equation.

If data cannot be pooled across trials the precision is based on

$$\sum_{i=1}^{n}(1-\hat{\tau}_i)/n = 1-\sum_{i=1}^{n}\hat{\tau}_i/n = 1-\bar{\hat{\tau}} \ .$$

Precision is defined as

$$P(|\bar{\hat{\tau}}-\bar{\tau}|<\varepsilon) = 1-\alpha$$

$$P(-\varepsilon<\bar{\hat{\tau}}-\bar{\tau}|<\varepsilon) = 1-\alpha$$

$$P\left(\frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}} < t_{n-1} < \frac{\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}}\right) = 1-\alpha$$

$$P\left(t_{n-1} < \frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}} \right) = \alpha / 2$$

$$\Phi\left(\frac{-\varepsilon}{Var(\bar{\hat{\tau}})} \right) = \alpha / 2$$

$$\frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}} = t_{\alpha/2,n-1}$$

$$Var(\bar{\hat{\tau}}) = \frac{\varepsilon^2}{t^2_{1-\alpha/2,n-1}}$$

$$\frac{\sigma_\tau^2 + \frac{\tau}{SP_A}\left[\frac{(1-S\tau P_A)}{R_T} + \frac{(1-SP_A)\tau}{R_C} \right]}{n} = \frac{\varepsilon^2}{t^2_{1-\alpha/2,n-1}}$$

where σ_τ^2=natural variation in passage-related mortality.

Now letting R_T=R_C

$$\frac{\sigma_\tau^2 + \frac{\tau}{SP_A}\left[\frac{(1-S\tau P_A)}{R} + \frac{(1-SP_A)\tau}{R} \right]}{n} = \frac{\varepsilon^2}{t^2_{1-\alpha/2,n-1}}$$

which must be iteratively solved for n given R. Or R given n where

$$R = \frac{\frac{\tau}{SP_A}\left[(1-S\tau P_A) + (1-SP_A)\tau \right]}{\left[\frac{n\varepsilon^2}{t^2_{1-\alpha/2,n-1}} - \sigma_\tau^2 \right]}$$

$$R = \frac{\frac{\tau(1+\tau)}{SP_A}}{\left[\frac{n\varepsilon^2}{t^2_{1-\alpha/2,n-1}} - \sigma_\tau^2 \right]}$$

$$R = \frac{\tau(1+\tau)}{SP_A}\left[\frac{t^2_{1-\alpha/2,n-1}}{n\varepsilon^2 - \sigma_\tau^2 t^2_{1-\alpha/2,n-1}} \right].$$

The joint likelihood for the passage-related mortality is:

$$L\,(S,\ \tau,\ P_A,\ P_D \mid R_C,\ R_T,\ a_C,\ a_T,\ d_C,\ d_T)=$$

$$\binom{R_C}{a_c d_C}(SP_A)^{a_C}((1-S)P_D)^{d_C}(1-SP_A-(1-S)P_D)^{R_C-a_C-d_C}$$

$$\times\binom{R_T}{a_T d_T}(S\tau P_A)^{a_T}((1-S\tau)P_D)^{d_T}(1-S\tau P_A-(1-S\tau)P_D)^{R_T-a_T-d_T}\ .$$

The likelihood model is based on the following assumptions: (1) fate of each fish is independent, (2) the control and treatment fish come from the same population of inference and share that same survival probability, (3) all alive fish have the same probability, P_A, of recapture, (4) all dead fish have the same probability, P_D, of recapture, and (5) passage survival (τ) and survival (S) to the recapture point are conditionally independent. The likelihood model has four parameters (P_A, P_D, S, τ) and four minimum sufficient statistics (a_C, d_C, a_T, d_T).

Because any two treatment releases were made concurrently with a single shared control group we used the likelihood model which took into account dependencies within the study design (Normandeau Associates *et al.* 1995). For any two treatment groups (denoted T_1 and T_2), the likelihood model is as follows:

$$L(S,\tau_1,\tau_2,P_A,P_D \mid R_C,R_{T_1},R_{T_2},a_C,d_c,a_{T_1},d_{T_1},a_{T_2},d_{T_2})=$$

$$\binom{R_C}{a_c d_C}(SP_A)^{a_C}((1-S)P_D)^{d_C}(1-SP_A-(1-S)P_D)^{R_C-a_C-d_C}$$

$$\times\binom{R_{T_1}}{a_{T_1} d_{T_1}}(S\tau_1 P_A)^{a_{T_1}}((1-S\tau_1)P_D)^{d_{T_1}}(1-S\tau_1 P_A-(1-S\tau_1)P_D)^{R_{T_1}-a_{T_1}-d_{T_1}}$$

$$\times\binom{R_{T_2}}{a_{T_2} d_{T_2}}(S\tau_2 P_A)^{a_{T_2}}((1-S\tau_2)P_D)^{d_{T_2}}(1-S\tau_2 P_A-(1-S\tau_2)P_D)^{R_{T_2}-a_{T_2}-d_{T_2}}\ .$$

This likelihood model has the same assumptions as stated in Normandeau Associates and Skalski (2000a) but has five estimable parameters (S, τ_1, τ_2, P_A, and P_D). The survival rate for treatment T_1 is estimated by τ_1 and for treatment T_2, by τ_2. A likelihood ratio test with 1 degree of freedom was used to test for equality in survival rates between treatments τ_1 and τ_2 based on the hypothesis H_O: $\tau_1=\tau_2$ versus H_a: $\tau_1\neq\tau_2$.

Likelihood models are based on the following assumptions: (a) the fate of each fish is independent; (b) the control and treatment fish come from the same population of inference and share the same natural survival probability, S; (c) all alive fish have the same probability, P_A, of recapture; (d) all dead fish have the same probability, P_D, of recapture; and (e) passage survival (τ) and natural survival (S) to the recapture point are conditionally independent.

The estimators associated with the likelihood model 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 passage mortality ($1 - \hat{\tau}$) or survival ($\hat{\tau}$) are:

$$Var(1-\hat{\tau}) = Var(\hat{\tau}) = \frac{\tau}{SP_A}\left[\frac{(1-S\tau P_{A)}}{R_T} + \frac{(1-SP_A)\tau}{R_C}\right]$$

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

DERIVATION OF VARIANCE FOR WEIGHTED AVERAGE SURVIVAL ESTIMATE

The variance of a weighted average is estimated by the formula

$$\hat{\bar{\theta}}_W = \frac{\sum_{i=1}^{n} W_i \hat{\theta}_i}{\sum_{i=1}^{n} W_i}$$

with

$$\text{Var}\left(\hat{\bar{\theta}}_W\right) = \frac{\sum_{i=1}^{n} W_i \left(\hat{\theta}_i - \hat{\bar{\theta}}_W\right)^2}{(n-1)\sum_{i=1}^{n} W_i}$$

where $\hat{\bar{\theta}}_W$ = the weighted average,

$\hat{\theta}_i$ = the parameter estimate for the *i*th replicate,

W_i = weight.

Exhibit D

APPENDIX B

STATISTICAL OUTPUT OF IMMEDIATE AND LATENT SURVIVAL ESTIMATES FOR JUVENILE SALMONIDS RELEASED THROUGH THE NFB, LINK CHUTE AND UNIT 13 OUTFALL CHUTE,

MARCH 2008.

Exhibit D

Appendix B.

Immediate (1 hr) survival estimates for juvenile Chinook salmon passing through the NFB at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 244, 242 alive and 2 assigned dead; at 250 cfs:150 released, 149 alive and 1 assigned dead; at 400 cfs: 199 released, 199 alive and 0 assigned dead.

==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	0.9918	(0.0058)	{Control group survival
Pa = Pd	1.0	N/A	Recovery probability*
S2 =	0.9933	(0.0066)	250 cfs survival
S3 =	1.0	N/A	400 cfs* survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -17.6071

Tau = 1.0015 (0.0089) 250 cfs NFB/Control ratio
Tau = 1.0083 (0.0059) 400 cfs NFB/Control ratio

Z statistic for the equality of NFB survivals: 0.6315

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00003332	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00004415	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9869, 1.0162)	(0.9986, 1.0179)
95 percent:	(0.9841, 1.0189)	(0.9968, 1.0198)
99 percent:	(0.9787, 1.0244)	(0.9932, 1.0234)

==

Likelihood ratio statistic for equality of recovery probabilities: 0.0000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix B. (continued)

Immediate (1 hr) survival estimates for juvenile Chinook salmon passing through the Link Chute at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 244, 242 alive and 2 assigned dead; at 250 cfs:149 released, 148 alive and 1 assigned dead; at 400 cfs: 199 released, 197 alive and 1 assigned dead.

==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.

S1 = 0.9918 (0.0058) {Control group survival
Pa = Pd 0.9983 (0.0017) Recovery probability
S2 = 0.9933 (0.0067) 250 cfs survival
S3 = 0.9949 (0.0050) 400 cfs survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -31.2688

Tau = 1.0015 (0.0089) Link Chute w/ 250 cfs passing through NFB /Control ratio
Tau = 1.0032 (0.0077) Link Chute w/ 400 cfs passing through NFB/Control ratio

Z statistic for the equality of Link Chute survivals: 0.1419

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00003332	0.00000000	0.00000000	0.00000000
0.00000000	0.00000285	0.00000000	0.00000000
0.00000000	0.00000000	0.00004474	0.00000000
0.00000000	0.00000000	0.00000000	0.00002538

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9868, 1.0162)	(0.9904, 1.0159)
95 percent:	(0.9840, 1.0190)	(0.9880, 1.0183)
99 percent:	(0.9785, 1.0245)	(0.9832, 1.0231)

==

Likelihood ratio statistic for equality of recovery probabilities: 0.0035
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix B. (continued)

Latent (48 hr) survival estimates for juvenile Chinook salmon passing through the NFB at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 244, 238 alive and 6 assigned dead; at 250 cfs: 150 released, 148 alive and 2 assigned dead; at 400 cfs: 199 released, 196 alive and 3 assigned dead.

==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	0.9754	(0.0099)	{Control group survival
Pa = Pd	1.0	N/A	Recovery probability*
S2 =	0.9867	(0.0094)	250 cfs survival
S3 =	0.9849	(0.0086)	400 cfs survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -54.3410

Tau = 1.0115 (0.0141) 250 cfs NFB/Control ratio
Tau = 1.0098 (0.0136) 400 cfs NFB/Control ratio

Z statistic for the equality of NFB survivals: 0.0914

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00009830	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00008770	0.00000000
0.00000000	0.00000000	0.00000000	0.00007461

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9884, 1.0347)	(0.9875, 1.0321)
95 percent:	(0.9840, 1.0391)	(0.9832, 1.0363)
99 percent:	(0.9753, 1.0478)	(0.9748, 1.0447)

==

Likelihood ratio statistic for equality of recovery probabilities: -0.0001
Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Exhibit D

Appendix B. (continued)

Latent (48 hr) survival estimates for juvenile Chinook salmon passing through the Link Chute at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 244, 238 alive and 6 assigned dead; at 250 cfs: 149 released, 147 alive and 2 assigned dead; at 400 cfs: 199 released, 194 alive and 4 assigned dead.

==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim. std.err.	
S1 =	0.9754 (0.0099)	{Control group survival
Pa = Pd	0.9983 (0.0017)	Recovery probability
S2 =	0.9866 (0.0094)	250 cfs survival
S3 =	0.9798 (0.0100)	400 cfs survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -65.7161

Tau = 1.0114 (0.0141) Link Chute w/ 250 cfs passing through the NFB/Control ratio
Tau = 1.0045 (0.0145) Link Chute w/ 400 cfs passing through the NFB/Control ratio

Z statistic for the equality of Link Chute survivals: 0.3439

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00009830	0.00000000	0.00000000	0.00000000
0.00000000	0.00000285	0.00000000	0.00000000
0.00000000	0.00000000	0.00008888	0.00000000
0.00000000	0.00000000	0.00000000	0.00009997

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9882, 1.0347)	(0.9807, 1.0283)
95 percent:	(0.9838, 1.0391)	(0.9761, 1.0329)
99 percent:	(0.9751, 1.0478)	(0.9672, 1.0418)

==

Likelihood ratio statistic for equality of recovery probabilities: 0.1368
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix B. (continued)

Immediate (1 hr) survival estimates for juvenile steelhead passing through the NFB at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 274, 273 alive and 1 assigned dead; at 250 cfs:150 released, 150 alive and 0 assigned dead; at 400 cfs: 251 released, 250 alive and 1 assigned dead.
==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	0.9964	(0.0036)	{Control group survival
Pa = Pd	1.0	N/A	Recovery probability*
S2 =	1.0	N/A	250 cfs survival*
S3 =	0.9960	(0.0040)	400 cfs survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -13.1348

Tau = 1.0037 (0.0037) 250 cfs NFB /Control ratio
Tau = 0.9997 (0.0054) 400 cfs NFB/Control ratio

Z statistic for the equality of NFB survivals: 0.6115

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001327	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00001581

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9976, 1.0097)	(0.9908, 1.0086)
95 percent:	(0.9965, 1.0109)	(0.9891, 1.0103)
99 percent:	(0.9942, 1.0131)	(0.9857, 1.0136)

==

Likelihood ratio statistic for equality of recovery probabilities: 0.0000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix B. (continued)

Immediate (1 hr) survival estimates for juvenile steelhead passing through the Link Chute at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 274, 273 alive and 1 assigned dead; at 250 cfs: 152 released, 151 alive and 1 assigned dead; at 400 cfs: 252 released, 249 alive and 2 assigned dead.

===

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	0.9964	(0.0036)	{Control group survival
Pa = Pd	0.9985	(0.0015)	Recovery probability
S2 =	0.9934	(0.0066)	250 cfs survival
S3 =	0.9920	(0.0056)	400 cfs survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -31.8069

Tau = 0.9971 (0.0075) Link Chute w/ 250 cfs passing through the NFB/Control ratio
Tau = 0.9957 (0.0067) Link Chute w/ 400 cfs passing through the NFB/Control ratio

Z statistic for the equality of Link Chute survivals: 0.1383

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001327	0.00000000	0.00000000	0.00000000
0.00000000	0.00000217	0.00000000	0.00000000
0.00000000	0.00000000	0.00004300	0.00000000
0.00000000	0.00000000	0.00000000	0.00003149

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9847, 1.0094)	(0.9846, 1.0067)
95 percent:	(0.9823, 1.0118)	(0.9825, 1.0088)
99 percent:	(0.9777, 1.0164)	(0.9784, 1.0129)

===

Likelihood ratio statistic for equality of recovery probabilities: 0.7970
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix B. (continued)

Latent (48 hr) survival estimates for juvenile steelhead passing through the NFB at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 274, 273 alive and 1 assigned dead; at 250 cfs: 150 released, 149 alive and 1 assigned dead; at 400 cfs: 251 released, 250 alive and 1 assigned dead.

==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	0.9964	(0.0036)	{Control group survival
Pa = Pd	1.0	N/A	Recovery probability*
S2 =	0.9933	(0.0066)	250 cfs survival
S3 =	0.9960	(0.0040)	400 cfs survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -19.1421

Tau = 0.9970 (0.0076) 250 cfs NFB/Control ratio
Tau = 0.9997 (0.0054) 400 cfs NFB/Control ratio

Z statistic for the equality of NFB survivals: 0.2886

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001327	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00004415	0.00000000
0.00000000	0.00000000	0.00000000	0.00001581

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9845, 1.0095)	(0.9908, 1.0086)
95 percent:	(0.9821, 1.0119)	(0.9891, 1.0103)
99 percent:	(0.9774, 1.0165)	(0.9857, 1.0136)

==

Likelihood ratio statistic for equality of recovery probabilities: 0.0000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix B. (continued)

Latent (48 hr) survival estimates for juvenile steelhead passing through the Link Chute at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 274, 273 alive and 1 assigned dead; at 250 cfs:152 released, 151 alive and 1 assigned dead; at 400 cfs: 252 released, 246 alive and 5 assigned dead.

==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.
S1 = 0.9964 (0.0036) {Control group survival
Pa = Pd 0.9985 (0.0015) Recovery probability
S2 = 0.9934 (0.0066) 250 cfs survival
S3 = 0.9801 (0.0088) 400 cfs survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -44.6802

Tau = 0.9971 (0.0075) Link Chute w/ 250 cfs passing through the NFB/Control ratio
Tau = 0.9837 (0.0096) Link Chute w/ 400 cfs passing through the NFB/Control ratio

Z statistic for the equality of Link Chute survivals: 1.1011

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001327	0.00000000	0.00000000	0.00000000
0.00000000	0.00000217	0.00000000	0.00000000
0.00000000	0.00000000	0.00004300	0.00000000
0.00000000	0.00000000	0.00000000	0.00007778

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9847, 1.0094)	(0.9680, 0.9994)
95 percent:	(0.9823, 1.0118)	(0.9649, 1.0024)
99 percent:	(0.9777, 1.0164)	(0.9591, 1.0083)

==

Likelihood ratio statistic for equality of recovery probabilities: 1.3603
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Exhibit D

Appendix B. (continued)

Immediate (1 hr) and latent (48 hr) survival estimates for juvenile steelhead passing through the Unit 13 Bypass Outfall Chute at with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 274, 273 alive and 1 assigned dead; at old outfall: 103 released, 103 alive and 0 assigned dead.

===

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	0.9964	(0.0036)	{Control group survival
Pa = Pd	1.0	N/A	Recovery probability*
S2 =	1.0	N/A	Old outfall survival*
S3 =	0.9934	(0.0066)	Link 250 cfs survival

* -- Because of contraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -12.6319

Tau = 1.0037 (0.0037) Unit 13 Bypass Outfall Chute/Control ratio

Z statistic for the equality of equal turbine survivals: 0.7888

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001327	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00004300

Confidence intervals:

Old outfall Tau

90 percent: (0.9976, 1.0097)
95 percent: (0.9965, 1.0109)
99 percent: (0.9942, 1.0131)

===

Likelihood ratio statistic for equality of recovery probabilities: -0.0003
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Exhibit D

Appendix B. (continued)

Combined malady rates for juvenile Chinook salmon passing through the NFB at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 244, 243 alive no maladies and 1 with maladies; at 250 cfs: 149 released, 148 alive no maladies and 1 with maladies; at 400 cfs: 199 released, 198 no maladies and 1 with maladies.
==
RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
estim. std.err.
S1 = 0.9959 (0.0041) {Control group clean fish rate
Pa = Pd 1.0 N/A Recovery probability*
S2 = 0.9933 (0.0067) 250 cfs clean fish rate
S3 = 0.9950 (0.0050) 400 cfs clean fish rate

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -18.7865

Tau = 0.9974 (0.0079) 250 cfs NFB/Control ratio
1-Tau = 0.0026 (0.0079) 250 cfs NFB/Control ratio
Tau = 0.9991 (0.0065) 400 cfs NFB/Control ratio
1-Tau = 0.0009 (0.0065) 400 cfs NFB/Control ratio

Z statistic for the equality of NFB clean fish rates: 0.1660

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001673	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00004474	0.00000000
0.00000000	0.00000000	0.00000000	0.00002512

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9844, 1.0103)	(0.9884, 1.0098)
95 percent:	(0.9820, 1.0128)	(0.9863, 1.0118)
99 percent:	(0.9771, 1.0176)	(0.9823, 1.0158)

==
Likelihood ratio statistic for equality of recovery probabilities: -0.0005
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix B (continued)

Combined malady rates for juvenile Chinook salmon passing through the Link Chute at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 244, 243 alive no maladies and 1 with maladies; at 250 cfs: 148 released, 148 alive no maladies and 0 with maladies; at 400 cfs: 197 released, 196 no maladies and 1 with maladies.

===

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	0.9959	(0.0041)	{Control group malady free rate
Pa = Pd	1.0	N/A	Recovery probability*
S2 =	1.0	N/A	250 cfs malady free rate*
S3 =	0.9949	(0.0051)	400 cfs malady free rate

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -12.7758

Tau = 1.0041 (0.0041) Link Chute w/ 250 cfs passing through the NFB/Control ratio
1-Tau = 0.0000 (0.0041) Link Chute w/ 250 cfs passing through the NFB/Control ratio
Tau = 0.9990 (0.0065) Link Chute w/ 400 cfs passing through the NFB/Control ratio
1-Tau = 0.0010 (0.0065) Link Chute w/ 400 cfs passing through the NFB/Control ratio

Z statistic for the equality of equal Link Chite malady free rates: 0.6598

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001673	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00002564

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9973, 1.0109)	(0.9883, 1.0098)
95 percent:	(0.9960, 1.0122)	(0.9862, 1.0118)
99 percent:	(0.9935, 1.0147)	(0.9822, 1.0158)

===

Likelihood ratio statistic for equality of recovery probabilities: 0.0000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Exhibit D

Appendix B (continued)

Major malady rates for juvenile Chinook salmon passing through the NFB at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 244, 243 alive no major maladies and 1 with major maladies; treatment 250 cfs: 149 released, 149 alive no major maladies and 0 with major maladies; treatment 400 cfs: 199 released, 198 alive no major maladies and 1 with major maladies.

===

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.

S1 = 0.9959 (0.0041) {Control group malady free rate

Pa = Pd 1.0 N/A Recovery probability*

S2 = 1.0 N/A 250 cfs major malady free rate*

S3 = 0.9950 (0.0050) 400 cfs major malady free rate

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -12.7859

Tau = 1.0041 (0.0041) 250 cfs/Control ratio

1-Tau = 0.0000 (0.0041) 250 cfs NFB/Control ratio

Tau = 0.9991 (0.0065) 400 cfs/Control ratio

1-Tau = 0.0009 (0.0065) 400 cfs NFB/Control ratio

Z statistic for the equality of major malady free rates: 0.6560

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001673	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00002512

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9973, 1.0109)	(0.9884, 1.0098)
95 percent:	(0.9960, 1.0122)	(0.9863, 1.0118)
99 percent:	(0.9935, 1.0147)	(0.9823, 1.0158)

===

Likelihood ratio statistic for equality of recovery probabilities: -0.0004

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706

For significance level 0.05: 3.841

For significance level 0.01: 6.635

Appendix B (continued)

Major malady rates for juvenile Chinook salmon passing through the Link Chute at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 244, 243 alive no major maladies and 1 with major maladies; treatment 250 cfs: 148 released, 148 alive no major maladies and 0 with major maladies; treatment 400 cfs: 197 released, 197 alive no major maladies and 0 with major maladies.

==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.
S1 = 0.9959 (0.0041) {Control group malady free rate
Pa = Pd 1.0 N/A Recovery probability*
S2 = 1.0 N/A 250 cfs major malady free rate*
S3 = 1.0 N/A 400 cfs major malady free rate*

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -6.4951

Tau = 1.0041 (0.0041) 250 cfs/Control ratio
1-Tau = 0.0000 (0.0041) 250 cfs NFB/Control ratio
Tau = 1.0041 (0.0041) 400 cfs/Control ratio
1-Tau = 0.0000 (0.0041) 400 cfs NFB/Control ratio

Z statistic for the equality of major malady free rates: 0.0000

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001673	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9973, 1.0109)	(0.9973, 1.0109)
95 percent:	(0.9960, 1.0122)	(0.9960, 1.0122)
99 percent:	(0.9935, 1.0147)	(0.9935, 1.0147)

==

Likelihood ratio statistic for equality of recovery probabilities: -0.0002
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix B. (continued)

Combined malady rates for juvenile steelhead passing through the NFB at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Combined Control fish released: 273, 272 alive no maladies and 1 with malady; at 250 cfs: 150 released, 150 alive no maladies and 0 with maladies; at 400 cfs: 250 released, 249 no maladies and 1 with maladies.
===

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
estim. std.err.
S1 = 0.9963 (0.0037) {Control group malady free rate
Pa = Pd 1.0 N/A Recovery probability*
S2 = 1.0 N/A 250 cfs malady free rate*
S3 = 0.9960 (0.0040) 400 cfs malady free rate

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -13.1271

Tau = 1.0037 (0.0037) 250 cfs NFB/Control ratio
1-Tau = 0.0000 (0.0037) 250 cfs NFB/Control ratio
Tau = 0.9997 (0.0054) 400 cfs NFB/Control ratio
1-Tau = 0.0003 (0.0054) 400 cfs NFB/Control ratio

Z statistic for the equality of NFB malady free rates: 0.6117

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001337	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00001594

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9976, 1.0097)	(0.9907, 1.0086)
95 percent:	(0.9965, 1.0109)	(0.9890, 1.0103)
99 percent:	(0.9942, 1.0132)	(0.9857, 1.0137)

===

Likelihood ratio statistic for equality of recovery probabilities: 0.0000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix B. (continued)

Combined malady rates for juvenile steelhead passing through the Link Chute at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Combined Control fish released: 273, 272 alive no maladies and 1 with malady; at 250 cfs: 152 released, 149 alive no maladies and 3 with maladies; at 400 cfs: 249 released, 248 no maladies and 1 with maladies.
==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.
S1 = 0.9963 (0.0037) {Control group malady free rate
Pa = Pd 1.0 N/A Recovery probability*
S2 = 0.9803 (0.0113) 250 cfs malady free rate
S3 = 0.9960 (0.0040) 400 cfs malady free rate

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -27.8691

Tau = 0.9839 (0.0119) Link Chute w/ 250 cfs passing through the NFB/Control ratio
1-Tau = 0.0161 (0.0119) Link Chute w/ 250 cfs passing through the NFB/Control ratio
Tau = 0.9996 (0.0054) Link Chute w/ 400 cfs passing through the NFB/Control ratio
1-Tau = 0.0004 (0.0054) Link Chute w/ 400 cfs passing through the NFB/Control ratio

Z statistic for the equality of Link Chute malady free rates: 1.2070

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00001337	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00012728	0.00000000
0.00000000	0.00000000	0.00000000	0.00001606

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9643, 1.0034)	(0.9907, 1.0086)
95 percent:	(0.9606, 1.0072)	(0.9890, 1.0103)
99 percent:	(0.9533, 1.0145)	(0.9856, 1.0137)

==

Likelihood ratio statistic for equality of recovery probabilities: -0.0001
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Appendix B. (continued)

Major malady rates for steelhead passing through the NFB at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 273, 273 alive no major maladies and 0 with major maladies; treatment at 250 cfs: 150 released, 150 alive no major maladies and 0 with major maladies; treatment at 400 cfs: 250 released, 250 alive no major maladies and 0 with major maladies.

===

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	1.0	N/A	Control group malady free rate*
Pa = Pd	1.0	N/A	Recovery probability*
S2 =	1.0	N/A	250 cfs major malady free rate*
S3 =	1.0	N/A	400 cfs major malady free rate*

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : 0.0000

Tau = 1.0000 (0.0000) 250 cfs/Control ratio
1-Tau = 0.0000 (0.0000) 250 cfs NFB/Control ratio
Tau = 1.0000 (0.0000) 400 cfs/Control ratio
1-Tau = 0.0000 (0.0000) 400 cfs NFB/Control ratio

Z statistic for the equality of major malady free rates: 0.0036

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(1.0000, 1.0000)	(1.0000, 1.0000)
95 percent:	(1.0000, 1.0000)	(1.0000, 1.0000)
99 percent:	(0.9999, 1.0001)	(1.0000, 1.0000)

===

Likelihood ratio statistic for equality of recovery probabilities: 0.0000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

Exhibit D

Appendix B. (continued)

Major malady rates for juvenile steelhead passing through the Link Chute at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 273, 273 alive no major maladies and 0 with major maladies; treatment 250 cfs: 152 released, 151 alive no major maladies and 1 with major maladies; treatment 400 cfs: 249 released, 248 alive no major maladies and 1 with major maladies.

==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.

S1 = 1.0 N/A Control group major malady free rate*

Pa = Pd 1.0 N/A Recovery probability*

S2 = 0.9934 (0.0066) 250 cfs major malady free rate

S3 = 0.9960 (0.0040) 400 cfs major malady free rate

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -12.5360

Tau = 0.9934 (0.0066) Link Chute w/ 250 cfs passing through the NFB/Control ratio

1-Tau = 0.0066 (0.0066) Link Chute w/ 250 cfs passing through the NFB/Control ratio

Tau = 0.9960 (0.0040) Link Chute w/ 400 cfs passing through the NFB/Control ratio

1-Tau = 0.004 (0.0040) Link Chute w/ 400 cfs passing through the NFB/Control ratio

Z statistic for the equality of major malady free rates: 0.3335

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00004300	0.00000000
0.00000000	0.00000000	0.00000000	0.00001606

Confidence intervals:

	250 cfs Tau	400 cfs Tau
90 percent:	(0.9826, 1.0042)	(0.9894, 1.0026)
95 percent:	(0.9806, 1.0063)	(0.9881, 1.0038)
99 percent:	(0.9765, 1.0103)	(0.9857, 1.0063)

==

Likelihood ratio statistic for equality of recovery probabilities: 0.0000

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706

For significance level 0.05: 3.841

For significance level 0.01: 6.635

Appendix B. (continued)

Combined malady rates for juvenile steelhead passing through the Unit 13 Bypass Outfall Chute at 250 and 400 cfs with controls released into the tailrace of the T.W. Sullivan Powerhouse, March 2008.

Control fish released: 273, 272 alive no maladies and 1 with maladies; treatment: 103 released, 102 alive no maladies and 1 with malady;

==

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

estim. std.err.

S = 0.9963 (0.0037) Control group malady free rate

Pa = Pd 1.0 N/A Recovery probability*

Tau = 0.9939 (0.0104) Old Outfall Chute/Control ratio

1-Tau = 0.0061 (0.0104) Unit 13 Bypass Outfall Chute/Control ratio

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -12.237497

Variance-Covariance matrix for estimated probabilities:

0.00001 -0.00001

-0.00001 0.00011

Profile likelihood intervals:

	Old Outfall malady free rate	Old Outfall mortality
90 percent:	(0.9682, 1.0000)	(0.0000, 0.0318)
95 percent:	(0.9610, 1.0000)	(0.0000, 0.0390)
99 percent:	(0.9449, 1.0000)	(0.0000, 0.0551)

==

Likelihood ratio statistic for equality of recovery probabilities: 0.000000

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706

For significance level 0.05: 3.841

For significance level 0.01: 6.635

==

Exhibit D

APPENDIX C

INCIDENCE OF INJURY OBSERVED ON RECAPTURED JUVENILE SALMONIDS DURING THE HI-Z TAG EVALUATION AT THE T.W. SULLIVAN POWERHOUSE,

MARCH 2008.

Exhibit D

Appendix C.

Incidence of injury observed on recaptured juvenile Chinook salmon and steelhead following passage through the NFB, Link Chute and Unit 13 Bypass Outfall Chute at the T.W. Sullivan Powerhouse, spring 2008.

Date	Test Lot	Fish VI	Live / Dead		Maladies	Passage Malady	Probable Cause	Status
NFB 400 cfs- Chinook								
3/3/08	1	ZL5	alive	48h	LOE; Flesh tear at tag site	No	Tagging/Release	Minor
3/3/08	1	ZJ3	dead	24h	Predator marks	No	Predation	
3/5/08	3	L74	alive		LOE; Flesh tear at tag site	No	Tagging/Release	Minor
3/5/08	3	L48	dead	24h	LOE; Predator marks	No	Predation	
3/6/08	4	N38	dead	24h	Hemorrhaged internally	Yes	Undetermined	Major
NFB 250 cfs - Chinook								
3/9/08	7	K62	dead	24h	LOE; Necropsied, no obvious injuries	No	Tagging/Release	Minor
3/9/08	7	K67	alive	24h	Slight bruised behind head	Yes	Mechanical	Minor
Link Chute (400 cfs through the NFB) - Chinook								
3/3/08	1	J23	dead	24h	LOE; Necropsied, no obvious injuries	Yes	Undetermined	Minor
3/5/08	3	K71	dead	24h	Necropsied, no obvious injuries	No	Tagging/Release	Minor
3/5/08	3	K31	dead	48h	Necropsied, no obvious injuries	No	Tagging/Release	Minor
Link Chute (250 cfs through NFB) - Chinook								
3/9/08	7	K95	dead	24h	Necropsied, no obvious injuries	No	Tagging/Release	Minor
NFB 400 cfs - Steelhead								
3/7/08	5	P63	alive	48h	Flesh tear at tag site	No	Tagging/Release	Minor
3/13/08	11	V24	alive	48h	Damaged left operculum: torn	Yes	Shear/Mechanical	Minor
NFB 250 cfs - Steelhead								
3/10/08	8	O65	alive	48h	Flesh tear at tag site	No	Tagging/Release	
3/10/08	8	O48	dead	48h	Necropsied, no obvious injuries	No	Tagging/Release	Minor

Exhibit D

Appendix C. (continued)

Incidence of injury observed on recaptured juvenile Chinook salmon and steelhead following passage through the NFB, Link Chute and Unit 13 Bypass Outfall Chute at the T.W. Sullivan Powerhouse, spring 2008.

Date	Test Lot	Fish VI	Live / Dead		Maladies	Passage Malady	Probable Cause	Status
Link Chute (400 cfs through the NFB) - Steelhead								
3/8/08	6	A32	dead	48h	Necropsied, no obvious injuries	No	Tagging/Release	Minor
3/8/08	6	A43	dead	48h	Bruised head; Scrape behind left operculum	Yes	Mechanical	Major
3/8/08	6	A74	dead	48h	Necropsied, no obvious injuries	No	Tagging/Release	Minor
Link Chute (250 cfs through the NFB) - Steelhead								
3/10/08	8	N24	alive	48h	Scrape above right eye	Yes	Mechanical	Minor
3/10/08	8	M97	dead	1h	Abrasion / Scrape - on top of head	Yes	Mechanical	Major
3/12/08	10	V04	alive	48h	Small Scrape on head	Yes	Mechanical	Minor
Old Outfall Chute - Steelhead								
3/13/08	11	W67	alive	48h	Damaged right operculum: torn	Yes	Mechanical	Minor
Control - Chinook								
3/3/08	1	J04	alive	48h	Predator marks	No	Predation	
3/3/08	1	J08	dead	1h	Predator marks	No	Predation	
3/5/08	3	M35	dead	24h	Slight Hemorrhaged internally	Yes	Undetermined	Major
3/6/08	4	M62	dead	24h	Necropsied, no obvious injuries	No	Tagging/Release	Minor
3/9/08	7	M37	dead	24h	Necropsied, no obvious injuries	No	Tagging/Release	Minor
3/14/08	12	X15	dead	1h	Predator marks	No	Predation	
3/14/08	12	X35	dead	24h	Necropsied, no obvious injuries	No	Tagging/Release	Minor
Control - Steelhead								
3/7/08	5	S30	alive	48h	Bruised head	Yes	Mechanical	Minor

Exhibit D

APPENDIX D

INCIDENCE OF INJURY OBSERVED ON RECAPTURED JUVENILE SALMONIDS DURING THE MARK-RECAPTURE EVALUATION AT THE T.W. SULLIVAN POWERHOUSE,

MARCH 2008

Appendix D.

Incidence of injury observed on recaptured juvenile Chinook salmon and steelhead following passage through the inner forebay and upper portion of the Unit 13 Bypass (Reach-One) at the T.W. Sullivan Powerhouse, spring 2008.

Collection Date	Species	Length (mm)	Treatment/ Control	Live / Dead		Maladies	Probable Cause	Status
3/19/08	Chinook	188	T	alive	48h	Descaling on caudal P. >20%, <50%	Mechanical	Major
3/19/08	Chinook	140	T	alive	48h	>20%, <50% scale loss on left side	Mechanical	Major
3/19/08	Chinook	147	T	alive	48h	>20%, <50% descaling on right side	Mechanical	Major
3/19/08	Chinook	180	T	alive	48h	Descaling on caudel ped.	Mechanical	Minor
3/19/08	Chinook	146	T	alive	48h	20% descaling on right side	Mechanical	Minor
3/19/08	Chinook	140	T	alive	48h	Small amount of blood on tail	Unknown	Minor
3/19/08	Chinook	150	T	alive	48h	20% descaling on right side	Mechanical	Minor
3/20/08	Chinook	177	T	dead	24h	10% descaling both sides, small pinch injury located below dorsal fin	Mechanical	Major
3/19/08	Steelhead	182	C	alive	48h	Descaling < 20% both sides	Mechanical	Minor
3/19/08	Steelhead	186	T	alive	48h	Bruise 10mmx5mm on back between head and dorsal fin	Mechanical	Minor
3/20/08	Steelhead	194	T	alive	48h	Pinch marks forward of dorsal on both sides, scale loss <20%	Mechanical	Major

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APPENDIX E

ESTIMATED 48-HR DIRECT SURVIVAL OF JUVENILE SALMONIDS PASSING THROUGH NON-TURBINE EXIT ROUTES AT HYDROELECTRIC DAMS IN THE COLUMBIA RIVER BASIN.

Exhibit D

Appendix E.

Sample size, recapture and control survival rates, and estimated 48 h direct survival of juvenile salmonids in passing through non-turbine exit routes at hydroelectric dams in the Columbia River Basin. Estimates based on HI-Z tag methodology (Heisey et al. 1992). Source: Normandeau Associates and Skalski (2005).

Station	Exit Route	Species	Water Temp. (°C)	Sample Size	Head (ft)	Test Spill Volume (Kcfs)	Recapture Rates (%) Control	Recapture Rates (%) Treatment	Control Survival (%)	Passage Survival (%)
The Dalles, WA	Spillbay 3	Chinook salmon	15-17	270	81	10.5	97.0	94.1	97.0	95.5
	Spillbay 4[b]	Chinook salmon	15-17	271	81	10.5	97.0	97.4	97.0	99.3
	Spillbay 6[b]	Chinook salmon	15-17	210	81	4.5	96.2	94.3	96.2	99.0
	Spillbay 4	Chinook salmon	10-14	391	75-80	7.5-10.5	98.7	96.7	98.0	97.4
	Spillbay 9	Chinook salmon	10-14	396	75-80	4.5-7.5	98.7	95.4	98.0	97.4
	Spillbay 13	Chinook salmon	10-14	405	75-80	3.0-6.0	98.7	93.8	98.0	93.8
	Spillbay 2[g]	Chinook salmon	9-15	345	80-84	4.5	97.6	95.1	97.1	92.5
	Spillbay 2[g]	Chinook salmon	9-15	45	80-84	12.0	N/A	95.6	N/A	96.7
	Spillbay 2[h]	Chinook salmon	9-15	45	80-84	12.0	N/A	100.0	N/A	100.0
	Spillbay 2[g]	Chinook salmon	9-15	120	80-84	12.0	98.9	99.2	98.9	100.0
	Spillbay 2[h]	Chinook salmon	9-15	120	80-84	12.0	98.9	98.3	98.9	96.9
	Spillbay 4[g]	Chinook salmon	9-15	345	80-84	4.5	98.2	98.3	98.2	96.5
	Spillbay 4[g]	Chinook salmon	9-15	120	80-84	12.0	98.9	98.3	98.9	99.5
	Spillbay 4[h]	Chinook salmon	9-15	120	80-84	12.0	98.9	99.2	98.9	98.6
	Spillbay 2[g]	Chinook salmon	13-16	190	75-79	9.0	100	98.9	98.9	97.5
	Spillbay 2[f,g]	Chinook salmon	13-16	189	75-79	9.0	100.0	95.8	98.9	93.1
	Spillbay 2[g]	Chinook salmon	13-16	110	74-80	12.0	99.2	100.0	99.2	98.5
	Spillbay 2[f,g]	Chinook salmon	13-16	108	74-80	12.0	99.2	98.1	99.2	99.3
	Spillbay 2[g]	Chinook salmon	13-16	149	76-79	18.0	98.6	100.0	98.2	100.0
	Spillbay 2[f,g]	Chinook salmon	13-16	150	76-79	18.0	98.6	100.0	98.2	99.2
	Spillbay 2[h]	Chinook salmon	13-16	149	75-80	18.0	98.6	99.3	98.2	99.2
	Spillbay 2[f,h]	Chinook salmon	13-16	150	75-79	18.0	98.6	98.7	98.2	97.8
	Spillbay 2[g]	Chinook salmon	13-16	100	77-78	21.0	99.4	100.0	99.4	98.2
	Spillbay 2[f,g]	Chinook salmon	13-16	100	77-80	21.0	99.4	100.0	99.4	93.1
	Spillbay 2[h]	Chinook salmon	13-16	100	76-77	21.0	99.4	98.0	99.4	95.1
	Spillbay 2[f,h]	Chinook salmon	13-16	100	76-78	21.0	99.4	100.0	99.4	98.2
	Spillbay 4[g]	Chinook salmon	13-16	241	74-78	9.0	100.0	97.5	98.9	96.6
	Spillbay 4[g]	Chinook salmon	13-16	160	74-79	12.0	99.2	98.8	99.2	99.9

Exhibit D

Appendix E. (continued)

Sample size, recapture and control survival rates, and estimated 48 h direct survival of juvenile salmonids in passing through non-turbine exit routes at hydroelectric dams in the Columbia River Basin. Estimates based on HI-Z tag methodology (Heisey et al. 1992). Source: Normandeau Associates and Skalski (2005).

Station	Exit Route	Species	Water Temp (°C)	Sample Size	Head (ft)	Test Spill Volume (Kcfs)	Recapture Rates (%) Control	Recapture Rates (%) Treatment	Control Survival (%)	Passage Survival (%)
The Dalles, WA	Spillbay 4[g]	Chinook salmon	13-16	200	77-79	18.0	98.6	100.0	98.2	99.7
	Spillbay 4[h]	Chinook salmon	13-16	209	75-79	18.0	98.6	98.1	98.2	97.3
	Spillbay 2	Chinook salmon	10-11	145	79-84	10.2-12.4	99.3	97.2	98.6	97.2
	Spillbay 2	Chinook salmon	10-11	145	79-84	11.0-13.2	99.3	97.9	98.6	99.3
	Spillbay 4	Chinook salmon	10-11	146	79-84	10.2-12.4	99.3	98.6	98.6	100
	Spillbay 4	Chinook salmon	10-11	145	79-84	11.0-14.7	99.3	97.9	98.6	98.6
	Spillbay 4[f]	Chinook salmon	10-11	145	79-84	10.3-11.0	99.3	100.0	98.6	100
	Spillbay 4[f]	Chinook salmon	10-11	144	79-84	11.0-14.7	99.3	99.3	98.6	98.6
	Spillbay 6[c]	Chinook salmon	10-11	39	79-84	7.4-12.4	99.3	92.3	98.6	959
	Spillbay 2	Chinook salmon	14-15	150	76-81	15.2-20.1	98.9	99.3	99.6	99.0
	Spillbay 2	Chinook salmon	14-15	150	76-81	17.6-20.6	98.9	100.0	99.6	97.7
	Spillbay 4	Chinook salmon	14-15	165	76-81	15.2-20.4	98.9	98.8	99.6	96.1
	Spillbay 4	Chinook salmon	14-15	149	76-81	17.5-20.5	98.9	98.7	99.6	.99.0
	Spillbay 4[f]	Chinook salmon	14-15	155	76-81	15.2-20.4	98.9	100.0	99.6	97.8
	Spillbay 4[f]	Chinook salmon	14-15	150	76-81	14.0-20.5	98.9	100.0	99.6	99.7
	Spillbay 6[c]	Chinook salmon	14-15	149	76-81	13.9-17.5	98.9	89.5	99.6	85.1
Wanapum, WA	Sluice	Chinook salmon	5-8	195	79	2.0	100.0	97.9	100.0	97.4
	Spillbay 2	Chinook salmon	5-8	235	79	4.3	100.0	99.6	99.6	99.6
	Spillbay 3[a]	Chinook salmon	5-8	235	79	4.3	100.0	97.9	99.6	95.7
	Spillbay 12[b]	Chinook salmon	5-8	155	79	2.0	100.0	97.4	100.0	92.0
	Spillbay 12[b]	Chinook salmon	5-8	160	79	4.0	96.7	98.8	96.7	96.9
	Spillbay 3	Chinook salmon	17-18	180	82	2.8	100.0	100.0	94.5	100.0
	Spillbay 4	Chinook salmon	17-18	244	82	6.0	100.0	99.6	95.8	99.3
	Spillbay 5	Chinook salmon	17-18	130	82	11.5	98.4	99.2	94.3	94.6
	Spillbay 4[a]	Chinook salmon	17-18	200	82	2.8	100.0	100.0	96.5	99.0
	Spillbay 4[a]	Chinook salmon	17-18	199	82	6.0	100.0	98.5	95.3	97.6
	Spillbay 4[a]	Chinook salmon	17-18	191	82	11.5	98.4	96.7	94.3	92.8
	Spillbay 3	Chinook salmon	16	180	82	2.8	100.0	100.0	97.5	99.4
	Spillbay 3	Chinook salmon	16	169	82	6.0	100.0	100.0	95.8	97.6
	Spillbay 3	Chinook salmon	16	198	82	7.5	100.0	100.0	94.3	99.5
	Spillbay 3[a]	Chinook salmon	16	180	82	2.8	100.0	100.0	96.5	98.3
	Spillbay 5[a]	Chinook salmon	16	170	82	6.0	100.0	98.8	95.3	98.2

Exhibit D

Appendix E. (continued)

Sample size, recapture and control survival rates, and estimated 48 h direct survival of juvenile salmonids in passing through non-turbine exit routes at hydroelectric dams in the Columbia River Basin. Estimates based on HI-Z tag methodology (Heisey et al. 1992). Source: Normandeau Associates and Skalski (2005).

Station	Exit Route	Species	Water Temp (°C)	Sample Size	Head (ft)	Test Spill Volume (Kcfs)	Recapture Rates (%) Control	Recapture Rates (%) Treatment	Control Survival (%)	Passage Survival (%)
Wanapum, WA	Spillbay 5[a]	Chinook salmon	16	210	82	7.5	100.0	99.0	82.3	97.6
	Bypass Pipe	Chinook salmon	16	500	76-80	0.4	99.6	99.8	99.6	100.0
	Spillbay 12[a,b]	Chinook salmon	5-6	300	81-82	10.4-12.5	100.0	99.0	97.3	99.0
Bonneville, WA	Spillbay 2	Chinook salmon	15-17	280	60	12.0	96.1	96.8	96.1	100.0
	Spillbay 4[a]	Chinook salmon	15-17	280	60	12.0	96.1	99.3	96.1	100.0
	Spillbay 14[a]	Chinook salmon	12-14	130	54-58	3.2-4.8	100.0	97.7	97.7	97.9
	Spillbay 16[a*]	Chinook salmon	12-14	166	54-58	3.2-6.4	100.0	95.8	97.7	95.9
	Spillbay 14[a]	Chinook salmon	12-14	238	50-55	5.1-7.9	95.4	98.3	97.7	98.6
	Spillbay 16[a*]	Chinook salmon	12-14	241	50-55	7.1-9.8	95.4	97.1	97.7	99.0
	Spillbay 14[a]	Chinook salmon	20-21	208	60-65	4.0-4.1	86.9	83.7	82.6	90.5
	Spillbay 16[a*]	Chinook salmon	20-21	185	60-65	5.0-6.0	86.9	88.1	82.6	88.6
	Spillbay 14[a]	Chinook salmon	20-21	250	60-64	5.0-6.0	87.6	87.6	82.6	100.0
	Spillbay 16[a*]	Chinook salmon	20-21	250	60-64	6.9-7.9	87.6	89.6	82.6	100.0
	Powerhouse I sluice	Chinook salmon	15-17	100	60	0.2-0.3	NA	93.0	NA	93.0
	Powerhouse II sluice	Chinook salmon	15-17	100	60	0.7	NA	90.0	NA	89.0
	Powerhouse II sluice	Chinook salmon	14-16	250	50-58	1.0	99.6	100.0	99.6	99.6
	Powerhouse II sluice	Chinook salmon	14-16	251	50-58	2.5	99.6	100.0	99.6	100.0
	Powerhouse II sluice	Chinook salmon	16-18	348	63-67	1.0	99.4	100.0	99.4	100.0
	Powerhouse II sluice	Chinook salmon	16-18	345	63-67	2.5	99.4	100.0	99.4	99.4
Lower Granite, WA	Spillbay 2[a]	Chinook salmon	9-10	120	90	3.4	100.0	100.0	100.0	97.5
	Surface Bypass Collector[a]	Chinook salmon	9-10	120	90	3.4	100.0	99.2	100.0	95.8
	Spillbay 2[a]	Chinook salmon	8-10	130	90	3.4	92.1	94.6	92.1	97.6
	Surface Bypass Collector[a]	Chinook salmon	8-10	133	90	3.4	92.1	97.8	92.1	97.0
	Spillbay 2[a]	Chinook salmon	10-11	130	97-98	5.7	100.0	100.0	100.0	100.0
	Spillbay 1[a,b] (RSW)	Chinook salmon	10-11	260	97-99	7.0	100.0	99.2	100.0	98.1

Exhibit D

Appendix E. (continued)

Sample size, recapture and control survival rates, and estimated 48 h direct survival of juvenile salmonids in passing through non-turbine exit routes at hydroelectric dams in the Columbia River Basin. Estimates based on HI-Z tag methodology (Heisey et al. 1992). Source: Normandeau Associates and Skalski (2005).

Station	Exit Route	Species	Water Temp (°C)	Sample Size	Head (ft)	Test Spill Volume (Kcfs)	Recapture Rates (%) Control	Recapture Rates (%) Treatment	Control Survival (%)	Passage Survival (%)
Little Goose, WA	Spillbay 1	Steelhead	8-9	150	90	5.6	100.0	100.0	100.0	100.0
	Spillbay 1	Steelhead	8-9	150	90	9.5	100.0	100.0	100.0	100.0
	Spillbay 1	Steelhead	8-9	100	90	1.8	99.0	100.0	99.0	100.0
	Spillbay 3[c]	Steelhead	8-9	40	90	5.6	100.0	98.0	100.0	100.0
	Spillbay 3[c]	Steelhead	8-9	120	90	9.5	100.0	99.0	100.0	98.3
	Spillbay 3[a]	Steelhead	8-9	150	90	5.6	100.0	99.0	100.0	98.0
	Spillbay 1[a]	Steelhead	8-9	150	90	9.5	100.0	100.0	100.0	100.0
	Spillbay 1[a]	Steelhead	8-9	100	90	1.8	99.0	100.0	99.0	99.0
	Spillbay 3[a,c]	Steelhead	8-9	39	90	5.6	100.0	100.0	100.0	100.0
	Spillbay 3[a,c]	Steelhead	8-9	120	90	9.5	100.0	99.0	100.0	99.2
Ice Harbor, WA	Spillbay 5[a]	Chinook salmon	10-12	310	93-96	3.4-5.1	99.3	99.7	99.3	98.7
	Spillbay 5[a]	Chinook salmon	10-12	225	94-96	4.3-8.5	99.3	99.1	99.3	99.5
	Spillbay 5[a]	Chinook salmon	10-12	120	96-97	8.5	99.3	100.0	99.3	98.7
	Spillbay 1[a,g]	Chinook salmon	6-7	105	95-97	3.4	98.0	98.1	100.0	98.8
	Spillbay 5[a,g]	Chinook salmon	6-7	105	95-96	3.4	98.0	97.1	100.0	98.8
	Spillbay 1[a,g]	Chinook salmon	6-7	250	94-98	5.1	97.5	98.4	100.0	97.9
	Spillbay 5[a,g]	Chinook salmon	6-7	250	93-99	5.1	97.5	97.2	100.0	98.6
	Spillbay 1[a,h]	Chinook salmon	6-7	200	94-97	11.9	97.5	98.5	100.0	99.7
	Spillbay 5[a,h]	Chinook salmon	6-7	200	95-100	11.9	97.5	98.0	100.0	99.7
	Spillbay 1[a,g]	Chinook salmon	6-7	50	94	11.9	100.0	100.0	100.0	100.0
	Spillbay 5[a,g]	Chinook salmon	6-7	40	99-100	11.9	100.0	100.0	100.0	100.0
	Spillbay 5[a,g]	Chinook salmon	13-14	321	93-96	4.3	96.7	97.8	96.7	93.7
	Spillbay 5[a,g]	Chinook salmon	13-14	287	92-96	4.3	96.7	99.0	96.7	100.0
	Spillbay 5[a,h]	Chinook salmon	13-14	362	94-97	11.9	96.7	95.9	96.7	96.5
	Spillbay 5[a,g]	Chinook salmon	13-14	350	94-97	11.9	96.7	96.0	96.7	95.0
	Spillbay 2[a,b,h] (RSW)	Chinook salmon	6-9.5	180	96-97	8.5	99.7	98.3	99.7	99.2
	Spillbay 2[a,b,g] (RSW)	Chinook salmon	6-9.5	359	96-97	8.5	99.7	98.6	99.7	96.1
	Spillbay 2[a,b,g] (RSW)	Chinook salmon	6-9.5	357	96-97	8.5	99.7	98.6	99.7	96.9
	Spillbay 3[a,h]	Chinook salmon	6-9.5	180	96-97	8.5	99.7	98.9	99.7	98.6
	Spillbay 3[a,g]	Chinook salmon	6-9.5	360	96-97	8.5	99.7	99.4	99.7	98.9

Exhibit D

Appendix E. (continued)

Sample size, recapture and control survival rates, and estimated 48 h direct survival of juvenile salmonids in passing through non-turbine exit routes at hydroelectric dams in the Columbia River Basin. Estimates based on HI-Z tag methodology (Heisey et al. 1992). Source: Normandeau Associates and Skalski (2005).

Station	Exit Route	Species	Water Temp (°C)	Sample Size	Head (ft)	Test Spill Volume (Kcfs)	Recapture Rates (%) Control	Recapture Rates (%) Treatment	Control Survival (%)	Passage Survival (%)
Lower Monumental, WA	Spillbay 7[a,g]	Chinook salmon	14-15	310	97	8.5	99.7	98.4	96.1	96.7
	Spillbay 7[a,h]	Chinook salmon	14-15	340	97	8.5	99.7	98.2	96.1	94.9
	Spillbay 8[a,g]	Chinook salmon	14-15	271	97	8.5	99.7	98.9	96.1	100.0
	Spillbay 8[a,h]	Chinook salmon	14-15	265	97	8.5	99.7	99.6	96.1	100.0
Rock Island, WA	Spillbay 21[b,h]	Chinook salmon	4	250	41	1.9	NA	98.0	NA	95.1
	Spillbay 23[b]	Chinook salmon	4	250	41	10.0	NA	100.0	NA	98.4
	Spillbay 31[b]	Chinook salmon	13-14	200	41-49	2.5	100.0	99.5	99.5	99.5
	Spillbay 31[b]	Chinook salmon	13-14	200	41-49	10.0	100.0	100.0	99.5	99.5
	Spillbay 29[a,b,e]	Chinook salmon	14-15	200	40-43	2.5	100.0	99.5	100.0	99.0
	Spillbay 29[a,b]	Chinook salmon	14-15	200	40-43	2.5	100.0	100.0	100.0	100.0
	Spillbay 16[a,b,e]	Chinook salmon	9-10	200	39-43	2.5	100.0	99.5	100.0	99.0
	Spillbay 16[a,b]	Chinook salmon	9-10	200	39-43	2.5	100.0	100.0	100.0	99.0
North Fork, OR	Spillway	Chinook/coho	9-11	126	135	0.7	100.0	100.0	93.6	87.3
	Spillway	Chinook/coho	9-11	129	135	2.0	100.0	99.2	86.1	80.1
	Spillway	Steelhead	9-11	129	135	0.7	100.0	100.0	98.4	85.6
	Spillway	Steelhead	9-11	128	135	2.0	100.0	100.0	92.3	96.5

a Spillbay with flow deflector.
a* Spillbay with deep flow deflector.
b Overflow weir or slot to attract surface oriented juvenile salmonids.
c Fish released into head pond vortices upstream of tainter gates.
d Spill directed onto concrete slab; survival is relative to survival at another spillbay.
e Periphery release.
f Off-center release.
g Deep release.
h Shallow release.

Exhibit E

Evaluation of the Effects of Off Normal Powerhouse Configuration of Fish Guidance Efficiency at the T.W. Sullivan Hydroelectric Project, Willamette River, OR, Fall 2009

Exhibit E

ANNUAL REPORT

Evaluation of the Effects of Off-Normal Powerhouse Configurations on Fish Guidance Efficiency

2009

PREPARED FOR:
Portland General Electric Company

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December 2009

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This study should be cited as: Karchesky, C.M., and M. E. Hanks. 2009. Annual Report: Evaluation of the Effects of Off-Normal Powerhouse Configurations on Fish Guidance Efficiency, Fall 2009. Prepared for Portland General Electric.

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1.0 INTRODUCTION AND BACKGROUND

The Willamette Falls Hydroelectric project (FERC No. 2233) is located on the Willamette River at river mile 26.2, approximately 5 miles south of Portland, Oregon. Willamette Falls is a naturally occurring, 40-ft-high horseshoe shaped basalt rock formation with a low concrete gravity dam along its entire crest (Figure 1).

On 8 December 2005, Portland General Electric Company (PGE) was issued an Order by the Federal Energy Regulatory Commission (FERC) approving the Settlement Agreement and issuing a new license for the Willamette Falls Project. Contained in the new FERC license is "Ordering Paragraph E" which makes the conditions submitted by the National Marine Fisheries Service (NMFS) under section 18 of the Federal Power Act a requirement of the license. Among the conditions contained in the License is a stipulation that establishes a downstream juvenile salmonids passage protection goal for downstream migrating salmonids as they pass through the T.W. Sullivan powerhouse under normal operating conditions. Work associated with this License condition occurred over a three year period and was completed in Spring 2009 (see T.W. Sullivan Final Survival Performance Report, Karchesky and Pyper 2009).

In addition to the survival standard, the License also requires an evaluation to assess the effects on fish guidance efficiency (FGE) under conditions when one or two turbines are shutdown as a result of low river flow (as outlined in the T.W. Sullivan Powerhouse Operations Plan, PGE 2008). Based on the initial hydraulic modeling conducted by ENSR (2004), it appeared that the performance of the forebay fish guidance system was dependent on the hydraulic conditions created as the water enters the inner forebay and then passes along and through the trashracks. The initial modeling also showed that the hydraulic conditions in the inner forebay were affected when individual units were shutdown, which could potentially affect fish guidance performance. The operations plan used this information to guide which turbines could be shutdown that would have the least effect on forebay hydraulics and, in turn should minimize the affects of unit shutdown on fish guidance performance. This report provides a summary of the tests completed in Fall 2009, which were designed to evaluate the effects of single and two unit shutdown as outlined in the operations plan on FGE of spring Chinook passing through the T.W. Sullivan powerhouse and bypass system.

2.0 METHODS AND MATERIALS

Since 2007, we have used passive integrated transponder (PIT) tags to evaluate the proportion of smolts passing through each passage route at the T.W. Sullivan powerhouse (Karchesky *et al.* 2007; Karchesky *et al.* 2008). A PIT tag detection antenna was constructed specifically for the NFB and was installed in early 2007. The newly installed PIT tag antenna was similar to the existing antennas installed in the Unit 13 bypass between the Eicher screen and the evaluator catch tank (Figure 2).

As suggested by Skalski (2000), the PIT tag antennas were calibrated for detection efficiency concurrently with each individual test release. This was done to ensure that any variation in detection efficiency between replicates was accounted for and provided the most precise data for generating an overall estimate of FGE. Both antennas were calibrated during each test by releasing fish immediately upstream of the antenna.

As in previous evaluations, out-migrating hatchery Chinook were collected from the Unit 13 bypass evaluator. All fish selected for tagging were anesthetized, measured for length, and then injected with a standard 12mm PIT tag using methods similar to those described in PGE (2006). One treatment and two calibration release sites were designated, and the total number of fish allocated to each release site was based on the recommendations made by Karchesky and Pyper (2009). All tagged fish were held for approximately 24 hours after tagging before release. Treatment fish were released into the forebay approximately 20 feet downstream of the main head gates through a release port allowing fish to pass through the upper deck. Calibration fish were released immediately upstream of each PIT tag antenna.

The detection history of each individual fish was uploaded from each detection antenna to the PTAGIS database, operated by the Pacific States Marine Fisheries Commission (PSMFC). This database was queried and data were downloaded for analysis.

Estimates of FGE and their associated variances were calculated independently for each release scenario using formulas outlined in Karchesky and Pyper (2009).

3.0 RESULTS AND DISCUSSION

3.1 Overview

The focus of the fall 2009 testing was to evaluate the effects of a single unit or two unit shutdown on FGE as stipulated in the License. However other “off-normal” conditions associated with the operation of the fish bypass system were also evaluated. These additional test scenarios were conducted following consultation with the Fish Technical Committee (FTC), and were designed to provide additional information regarding the operation of the fish bypass system when conditions do not allow for normal operation.

A total of five different test scenarios using 3,970 juvenile Chinook (2,001 treatment, 1,723 NFB calibration, and 246 Unit 13 calibration) were conducted in fall 2009 (Table 1). The fork lengths of tagged Chinook averaged 171 mm (ranging 116 mm to 210 mm), which was consistent with those collected in the fall during previous years.

3.2 Hydraulic Conditions

In fall 2009, river flow recorded during each release trial varied among releases; river flow ranged from approximately 14Kcfs to about 23Kcfs (Figure 4). Operational head (difference between the forebay and tailrace water elevation) ranged from 41.8 to 43.75 ft (Table 2). Water temperatures recorded during the spring evaluation period gradually decreased from 10.4^{o} C to 8.4^{o} C.

3.3 PIT Tag Reader Efficiency

Variation in detection efficiencies between PIT tag antennas (i.e.., NFB and Unit 13) was similar to those reported in previous studies (Table 1; Karchesky et al. 2007; Karchesky et al. 2008). Also similar to previous studies, detection efficiencies were generally higher for juvenile Chinook passing through the Unit 13 bypass (averaging 89.8%) when compared to those passing through the NFB (averaging 85.8%).

3.4 Fish Guidance Efficiency

3.4.1 Single Unit Shutdown Scenario (Unit 11 offline)

A single unit shutdown scenario was tested using juvenile Chinook on 11 November. During this test, all turbine units were on except for Unit 11 (as stipulated in the Operations Plan, PGE 2008), and the NFB was operating at 400 cfs. The treatment group consisted of 394 smolts, and the calibration groups for the NFB and Unit 13 PIT tag antennas consisted of 333 and 46 smolts, respectively. After adjusting for detection efficiency at each antenna, the estimated FGE under the single unit shutdown scenario was 100% with a 95% confidence interval of ± 6%.

The results of this evaluation validate the recommendations made by ENSR (2004). Using hydraulic modeling, they identified either Unit 10 or Unit 11 be selected if a single unit shutdown was required and still maintain favorable hydraulic conditions for the fish bypass system to operate properly.

3.4.2 Two Unit Shutdown (Units 4 & 9 offline)

A single test to evaluate the effects of a two unit shutdown on fish guidance performance was conducted on 12 November. Under this scenario all turbine units were operating except Units 4 and 9 (as stipulated in the Operations Plan, PGE 2008), and the NFB was operating at 400 cfs. A total 400 smolts were released in the treatment group along with an additional 347 smolts released to calibrate the NFB and 49 to calibrate the Unit13 PIT tag antennas (Table 1). After adjusting for detection efficiency, the estimated FGE was calculated to be 100% with an associated 95% confidence interval of ± 6%.

Similar to the results observed during the single unit shutdown, a two unit shutdown does not appear to affect the performance of the fish guidance system, and further validates the results of the hydraulic modeling and recommendations made by ENSR (2004).

3.4.3 Other “Off-Normal” Conditions

All Turbine Units On; Except Unit 13

We conducted two release scenarios to evaluate the affects of having Unit 13 offline on fish guidance performance. The initial scenario evaluated Unit 13 offline while all other units were operating and the NFB flow was set at 400 cfs. Although the Unit 13 was offline, 40 cfs continued to pass through the Unit 13 fish bypass route to alleviate any potential stranding issues. A total of 802 juvenile Chinook were released (401 treatment, 350 NFB Calibration, and 51 Unit 13 calibration). Of the 314 smolts detected downstream, only one was detected passing through the Unit 13 bypass. After adjusting for detection efficiency at each antenna, the estimated FGE was calculated to be 89% with an associated 95% confidence interval of ± 6%.

Because of the comparatively low FGE estimate observed for the initial test scenario, a second scenario was conducted while Unit 13 was offline, but with maximum flow of 500 cfs passing through the NFB. This was done in provide more attraction flow at the entrance of the NFB since only 40 cfs was passing through Unit 13. A total of 806 Chinook were released for either calibration (n = 401) or upstream as treatment (n = 405). Similar to the initial test, the majority (99%) of smolts detected downstream (n=310) passed through the NFB. After adjusting for detection efficiency at each antenna, the estimated FGE with Unit 13 offline and 500 cfs flow passing through the NFB was calculated to be 91% (±6%).

While both estimates of FGE were comparatively lower under this scenario than previously tested conditions, increasing flow from 400 cfs to 500cfs did appear to improve fish guidance performance. Still both estimates of FGE were with in the bounds necessary to achieve the performance standard.

All Units On; 250 cfs NFB Flow

It was important to assess the potential affects of reduced flow through the NFB on fish guidance performance to provide additional information on alternative operational configurations for the bypass system particularly during low river flows. Under this scenario, flow through the NFB was reduced from the previously tested condition of 400 cfs to 250 cfs while all turbine units were operating. A total of 793 smolts were released with the majority being released as treatment (n = 401) and NFB calibration (n = 342) fish. Of the fish released upstream, 335 were detected downstream; 92% of which were detected passing through the NFB while the remaining 8% were detected passing through the Unit 13 bypass. After adjusting for detection efficiency at each antenna, the estimated FGE at the reduced NFB flow was 95% with an associated confidence interval of 5%.

4.0 REFERENCES

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TABLES

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Table 1.

Summary of Chinook smolts PIT-tagged and released immediately upstream of the T.W. Sullivan Powerhouse to evaluate FGE, fall 2009.

Release Scenario	Release Date	Units Offline	NFB Discharge	NFB Calibration			Unit 13 Calibration			Treatment			FGE Estimate
				Released	Detected	%	Released	Detected	%	Released	NFB	Unit 13	
1	5-Nov	Unit 13[a]	400	350	308	88.0	51	46	90.2	401	313	1	89%
2	6-Nov	None	250	342	300	87.7	50	44	88.0	401	309	26	95%
3	11-Nov	Unit 11	400	333	285	85.6	46	41	89.1	394	332	10	100%
4	12-Nov	Units 4&9	400	347	291	83.9	49	42	85.7	400	339	5	100%
5	13-Nov	Unit 13[a]	500	351	293	83.5	50	48	96.0	405	306	4	91%

[a] Unit 13 was shutdown, however 40 cfs continued to pass through the Unit 13 bypass to alleviate any potential stranding issues.

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Table 2.

Summary of conditions recorded during each treatment released at the T.W. Sullivan Powerhouse, fall 2009.

Release date	Species	Water Temp C	River flow (Kcfs)	Trailrace elevation (MSL)	Forebay elevation (MSL)	Operational head (ft)	Weather Code[a]
11/05/2009	Chinook	10.4	14.9	9.25	52	42.75	3
11/06/2009	Chinook	10.4	15.2	9.4	51.2	41.8	3
11/11/2009	Chinook	8.9	24.6	10.2	53.1	42.9	3
11/12/2009	Chinook	8.6	25.4	9.25	53	43.75	3
11/13/2009	Chinook	9.6	25.8	9.4	53	43.6	3

[a] Weather code: 1 sunny; 2 partly cloudy; and 3 cloudy.

Exhibit E

FIGURES

Exhibit E

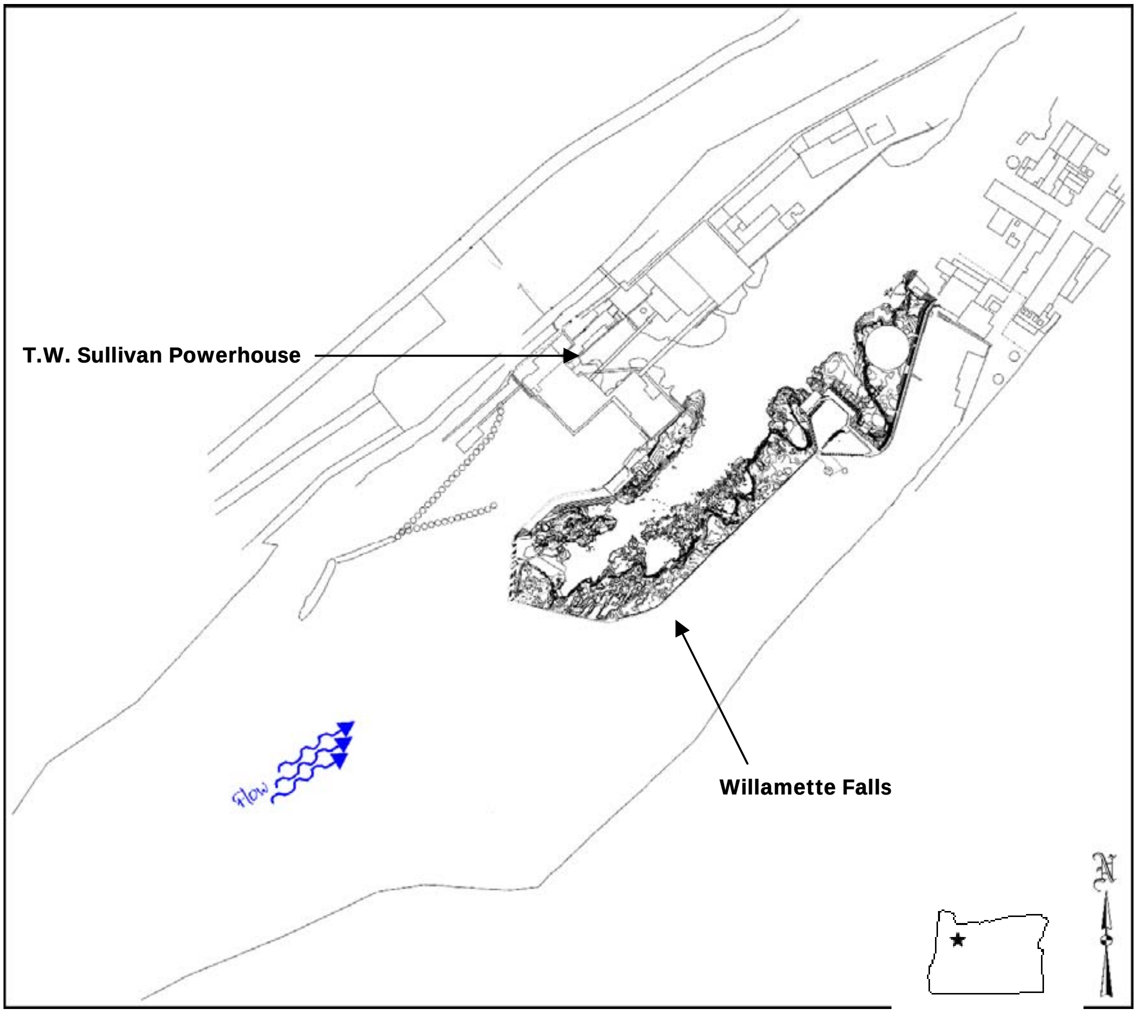

Figure 1.

Generalized layout of the Willamette Falls Project.

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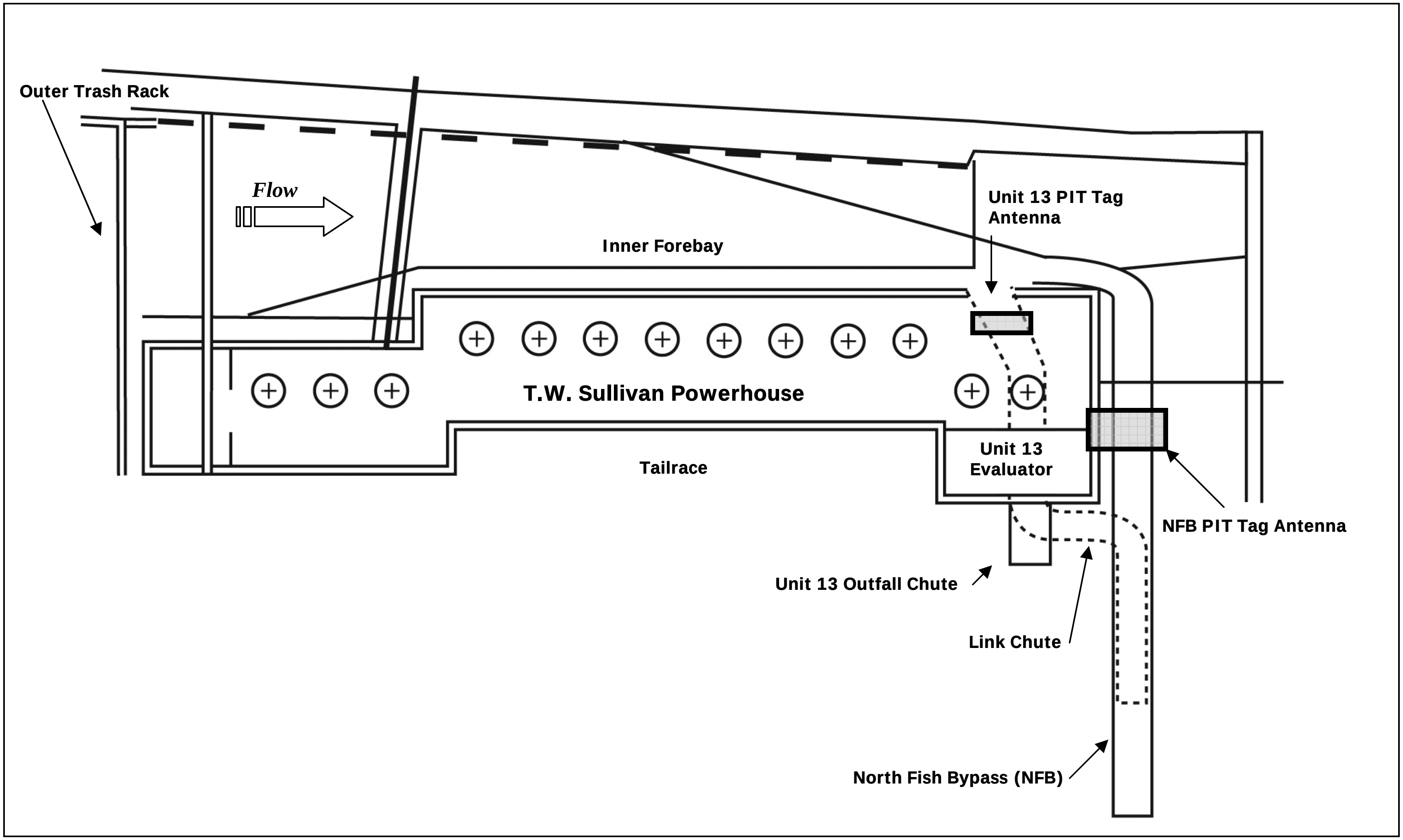

Figure 2.

T.W. Sullivan forebay and fish bypass facilities.

Exhibit E

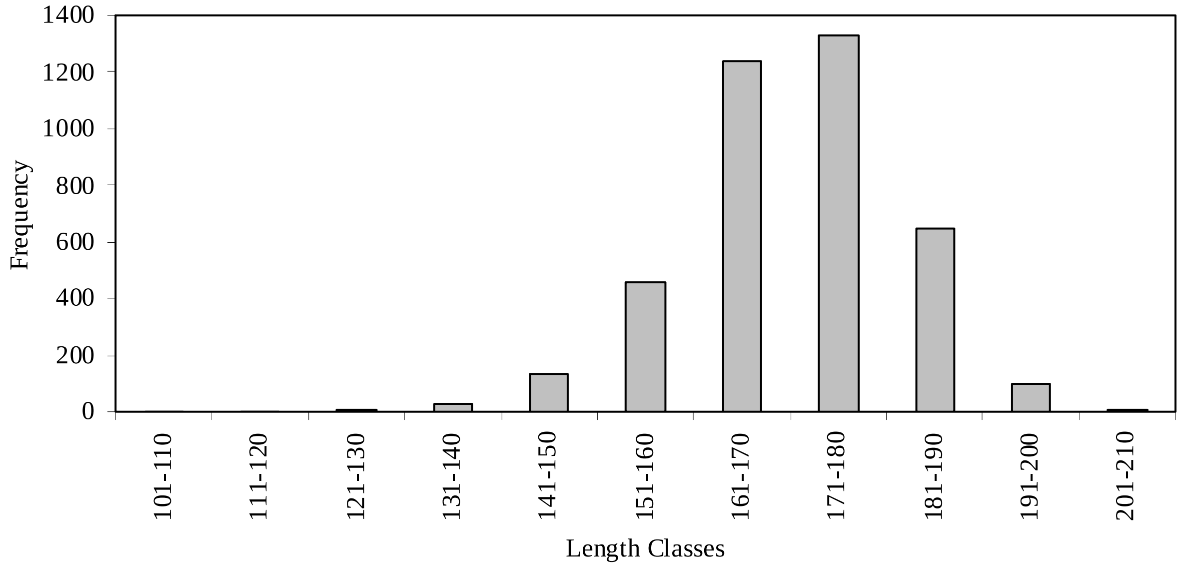

Figure 3.

Length frequency distribution of juvenile Chinook tagged and released at the T.W. Sullivan powerhouse to estimate FGE, fall 2009.

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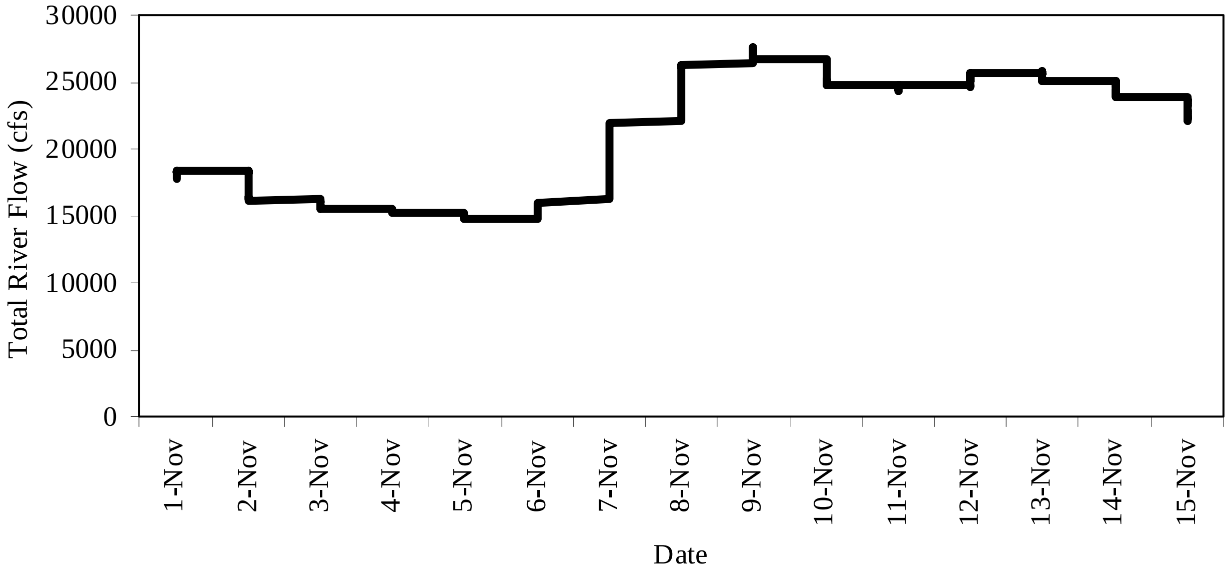

Figure 4.

Average daily river flow recorded at the USGS gauging station located at Salem (USGS gage no. 14191000 at RM 84.16, Willamette River), and adjusted for accretion recorded during the FGE evaluation period, fall 2009.