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MEMORANDUM

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TO: Kristin Meira, PNWA Director and the Inland Ports and Navigation Group (IPNG)

FROM: Jim Starkes and Mike Wert, David Evans and Associates, Inc.

SUBJECT: Columbia River System Operations (CRSO) FEIS, Limited Review

PROJECT: Task Order 2020-02, CRSO FEIS Review

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Summary

This memorandum provides a review of the Comparative Survival Study (CSS) model developed by the Fish Passage Center which is comprised of representatives from several federal, state, and tribal natural resources agencies. The CSS model is one of two models used to predict smolt-to-adult returns (SARs) of spring Chinook salmon and steelhead as described in the Columbia River System Operations (CRSO) Final Environmental Impact Statement (FEIS).

Developed by the National Marine Fisheries Service, the Life Cycle Model (LCM) also was used in the CRSO FEIS to predict SARs for spring Chinook salmon and steelhead. Although both models were applied for a similar purpose, they predicted vastly different magnitudes of SARs improvements when used to evaluate to the Multi-Objective 3 (MO3) Alternative which includes the scenario of breaching four Snake River dams.

As will be subsequently described in this review, the extreme and largely unexplained improvements in SARs forecasted by the CSS Model warrant additional scrutiny, especially when contrasted with the modest improvements predicted by the LCM. The following bullets briefly describe several limitations and concerns that call into question the validity of the CSS model predictions.

- The CSS model predicts smolt to adult survival increases of up to 170 percent for Alternative MO3, which would include the breaching of the four lower Snake River dams. This prediction is questionable given the fact that seaward migrating fish would still need to traverse an additional four dams downstream from the Snake River confluence while further encountering variable offshore conditions. In contrast, the LCM model predicts SARs would increase by up to 35 percent which more closely reflects environmental conditions encountered within the Columbia River System and open ocean where the migrating fish subsequently mature (see Section 2).

- Review of the FEIS and scientific literature reveals several limitations of the CSS Model relative to how it was applied to salmon run predictions in the Columbia River System.

- Limited scientific evidence based on verifiable data exists to support the premise of "delayed mortality" on which the CSS model's predictions rely. In fact, a substantial body of scientific literature developed

on the Columbia River calls into question, and expressly refutes, the validity of this premise (see Section 3).

- Research data from studies of juvenile fish passing over the Snake River dams verify that survival is high. This indicates that other environmental factors besides fish passage over these dams has a greater role in determining salmon returns (see Section 3).
- There have been significant declines in salmon survival rates that fall short of established survival goals in the Columbia basin from the mid-1990s to a record low in 2017. It appears implausible that breaching the four Snake River dams within the basin while leaving the four downriver dams intact would reverse so dramatically this trend that has persisted for more than two-decades (see Section 3).
- As recognized by the Independent Scientific Advisory Board (ISAB), the FEIS provides little to no explanation as to why the CSS model has generated such large differences in SARs among the evaluated alternatives, and particularly as to the basis for the extremely high level of improvements predicted under the MO3 Alternative which would include the breaching of the four Snake River dams (see Section 3).
- The CSS model fails to adequately account for the array of oceanic environmental conditions that are widely recognized as the most important and dynamic variables affecting juvenile salmon mortality. The model's principal reliance on in-river variables disregards the wide array of other oceanic environmental parameters that provide a greater degree of impact on salmon survival rates (see Section 4).
- Lastly, the CSS model fails to adequately consider impacts of climate change into the future, over large spatial extents. Science indicates this will alter water temperature and hydrological regimes, food abundance and distribution, and a myriad of other parameters in rivers and the ocean (see Section 5).

1. Introduction

This review, prepared by David Evans and Associates, Inc. (DEA), focuses on the Comparative Survival Study (CSS) Model, which is one of two models used to analyze smolt to adult survival (SAR) as part of the evaluation of alternatives in the CRSO FEIS. In particular, DEA reviewed the application and results of the CSS model relative to its assumptions, limited variables, data inputs, and purportedly high SAR predictions related to the Multiple Objective 3 (MO3) Alternative. A component of the MO3 Alternative would involve the breaching of four Snake River dams.

Our review focuses primarily on the following sections of the FEIS:

- Executive Summary
- Section 2.4, Range of Alternatives
- Section 3.5, Aquatic Habitat, Aquatic Invertebrates, and Fish
- Section 4.2.4, Climate – Anadromous Fish
- Section 7.7, Preferred Alternative
- Appendix E, Fish Aquatic Macroinvertebrates and Aquatic Habitats
- Appendix V, Endangered Species Act Consultation

Additionally, we note that several reports particularly relevant to the analysis of fisheries-and Endangered Species Act issues were evaluated including:

- Independent Scientific Advisory Board (ISAB) Review of Chapter 2 of the CSS (ISAB 2020)
- Fish Passage Center (2020) Chapter 2 of the CSS Annual Report for 2019 (released 2/28/2020)
- Peer-reviewed scientific literature

1.1. Alternatives Reviewed

This review focuses on the two multiple objective alternatives modeled by the Comparative Survival Study using the CSS model—Alternative MO3, Breach of 4 Snake River dams, and Alternative PA, the Preferred Alternative.

Alternative MO3. Alternative MO3 proposes to breach Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams on the lower Snake River. The four Middle Columbia River dams downstream would remain intact and would spill to the 120 percent total dissolved gas standard (TDG) levels. Since MO3 would involve breaching the Lower Snake projects, there would be no smolt transportation component or spring spill operations under this scenario. MO3 includes the installation of Powerhouse Surface Passage Structures (PSPs) at McNary Dam. Finally, MO3 includes several measures that may affect flows and water transit time (WTT), including: 1) changes at high head reservoir projects that may have led to decreases in flows in the Mid-Columbia River; 2) John Day Dam operating within its full reservoir operating range, which may lead to changes in WTT; and 3) turbines operating within and above the 1 percent peak efficiency during the spill season, which may result in higher powerhouse capacities (FEIS 2020; FPC 2020).

Preferred Alternative. The spring spill operations at each of the four Lower Snake River dams and McNary Dam in the Middle Columbia River under the Preferred Alternative would provide for 16 hours of spill up to the 125 percent TDG threshold and 8 hours of lower performance standard spill. At John Day Dam under this alternative, spring spill would occur for 16 hours up to the 120 percent TDG threshold and 8 hours of lower performance standard spill. At the Dalles Dam, spill would occur for 24 hours of 40 percent spill. Finally, at Bonneville, spill would occur for 16 hours up to 150 kilo cubic feet per second (Kcfs) and 8 hours of lower performance standard spill. Transportation of smolts would begin on April 20th.

The PA also included the installation of "fish friendly turbines" at Ice Harbor, McNary, and John Day dams. Additionally, several measures that may affect flows and WTT would be implemented, including: 1) changes at high head reservoir projects that may have led to decreases in flows in the Mid-Columbia River; 2) having John Day operate at a full reservoir operating range, which may affect WTT, and 3) operating turbines within and above the 1% peak efficiency during the spill season, which may result in higher powerhouse capacities (FEIS 2020; FPC 2020).

2. Review of models and methods used to predict smolt-to-adult returns (SARs).

The CSS and the LCM models used in the CRSO FEIS use different variables to predict survival rates of salmon with the CSS model predicting substantially higher survival compared to the LCM model predictions. Such differences in predicted survival warrant further scrutiny as to why the CSS model predictions are much greater and whether environmental variables were incorrectly emphasized or accounted for in its use.

Predictions of spring Chinook salmon and steelhead passage were developed for the FEIS analysis to assess fish survival and run size in response to structural and operational changes to CRS for the respective alternatives. The two models use different assumptions and different combinations of environmental variables to predict survival including how delayed smolt mortality factors into the respective analysis.

The benefits to salmon populations ascribed to the various alternatives are largely based on results of these models. Major attributes of these models include:

- CSS Model
  - Juvenile salmon and steelhead survival increases with increasing spring spill because this would reduce the number of powerhouses fish would encounter during their downstream migration. Traversing through powerhouses (or bypasses), rather than over the spillway, subjects juvenile fish to stress and injury from contact with turbines and other structures.
  - The CSS model predicts that delayed mortality is particularly important in determining survival and that stress from passing through multiple powerhouses frequently results in latent mortality that occurs before or after smolts reach the estuary.
- LCM Model
  - The LCM model is based on a broader range of ocean-related variables which, in combination with accounting for the abundance of fish transported around the dams, have a much greater influence in determining ocean survival and adult returns.
  - The LCM model attributes the majority of survival declines to the timing at which smolts enter the ocean (i.e., delays to estuary arrivals tend to reduce ocean survival) and deteriorating ocean conditions (decadal scale cycles in ocean productivity and warming water in the Northeast Pacific Ocean).

In the CRSO FEIS, both models were used to estimate the magnitude of effects on salmonids. Of particular interest, is the comparison of results of the two models which reflect large differences in survival with regard to Alternative MO3, the breaching of the 4 lower Snake River dams. While both models predict the highest potential SARs for Snake River Chinook salmon and steelhead for all the alternatives, the CSS Model predicts SARs would increase by 150 to 170 percent. The LCM Model, however, predicts a modest 14 to 35 percent increase. This difference warrants further technical scrutiny to validate model variables and assumptions relative to such disparate results. Such scrutiny will provide for more accurate prediction of SARs and the magnitude of benefits to fish associated with Alternative MO3.

As illustrated below, considerable concerns exists regarding the CSS model's predictions of salmon survival for Alternative MO3 compared to other Multiple Objective Alternatives.

3. Latent or Delayed Mortality

The primary driver of the CSS model's forecasts is the assumption of "latent" or "delayed mortality", a concept which does not have universal support within the scientific community. In fact, there is scientific evidence to indicate that delayed mortality is not the primary contributor to salmonid survival in the Columbia Basin.

The key premise of delayed mortality is that the migration of juvenile salmon to the estuary and ocean is slowed because of damage or fatigue from passage through the CRS and that this results in substantially lower marine survival rates. Specifically it is postulated that:

- Stress events experienced by smolting juvenile salmon caused by their passage through dam turbines, juvenile bypass systems, and spillways can result in delayed mortality. This suggests that cumulative effects to seaward migrating smolts encountering multiple dams in the Snake and Columbia river system can increase the vulnerability of these fish to predation and pathogens and reduce energy reserves, all of which in turn can reduce survival.

- Hydrosystems have substantially changed the flow regimes of the Snake and Columbia rivers thereby altering the historic rates of seaward migration by smolts which may be destabilizing previously established ocean entry timing. Such alterations may reduce subsequent survival.

- Transportation of smolts around the hydrosystem accelerates downstream passage which may lead to size-selective predation of the small fish in the lower river by northern pike minnow and in the estuary by Pacific hake. By comparison, in-river migrating smolts achieve greater length by a mean of 5-8 mm. Smolts transported directly to the lower river do not grow to as large a size as in-river migrants that achieve this destination without transport. The size of smolts as they travel from the estuary to offshore waters has been found to be a key factor in the ocean survival of salmonids (Muir et al. 2006).

The CSS model predicts that by increasing in-water transit time and spill over the dams, delayed mortality rates could be reduced resulting in a corresponding increase in SARs of upriver stocks of Chinook salmon and steelhead. This premise is indeed the principal factor driving the CSS model predictions of SARs.

However, though there are proponents of delayed mortality (e.g., Budy et al. 2002, Muir et al. 2006), there is little scientific evidence and concrete data to support this premise. In contrast, there is a substantial amount of study specific to the Columbia River, including peer-reviewed scientific literature, that either refutes or questions the validity of this premise, as summarized below:

- Welch et al. (2008) measured the survival of salmon smolts and found that survival during downstream migration of some Columbia and Snake River Chinook and steelhead stocks appears to be as high, or higher than that of the same species migrating out of the Fraser River, a large river system in southern British Columbia, which has no dams. Also of note, smolt survival during migration through the hydrosystem, when scaled by either time or distance migrated, was higher when compared with survival in the lower Columbia River and estuary where dams are absent. Their results raise important questions regarding the factors that are preventing the recovery of salmon stocks in the Columbia and Fraser basins.

- Rechisky et al. (2014) tested whether there was support for hydrosystem induced delayed mortality of migrating yearlings from the Snake River vs. migrating yearlings from the mid-Columbia River. They found no support for hydrosystem delayed mortality, as survival of in-river migrating Snake and mid-Columbia River yearlings was indistinguishable.

- Haeseker et al (2012) calculated seasonal, life-stage specific survival rate estimates for Snake River Chinook and steelhead, conducting multiple regression analyses to identify key freshwater and marine environmental factors associated with survival of each life stage. In doing so, the authors determined that certain freshwater variables (e.g., spillage over dams and water transit time) affected survival rates in freshwater, estuarine, and marine environments. However, they also determined the most important variable for characterizing SARs of both species was the Pacific Decadal Oscillation (PDO) Index.

- Faulkner et al. (2019) found that passage through bypass systems in the Columbia basin and subsequent adult returns was associated with the size of juvenile fish. Larger fish had a higher probability of surviving to adulthood. Further, bypass through dams were found to have had little association with adult returns after accounting for fish length.
- Similar to Faulkner et al. (2019) findings, Skalski (2013) also determined that once fish length was incorporated into their SAR model of Columbia basin salmonids, freshwater variables were no longer statistically significant.

Further evidence that suggests the contribution of delayed mortality does not play a primary role in survival is shown by examining mean survival of juvenile salmon passing over Snake and Columbia river dams. Overall fish passage survival data at these dams have been collected and are summarized in Table 1. Of note is that mean survival of juvenile salmon over the dams between 2010 and 2014 has been reported above 90 percent, with survival higher at three of the four Snake River dams compared to the four downriver Columbia River dams. Why would the CSS model predict such a substantial increase in survival with removal of the Snake River Dams since records indicate these dams have relatively higher survival than the Columbia River dams? It would seem the lower Columbia River dams, which result in somewhat less survival, could be more limiting to upper Columbia River and Snake River salmonid survival.

Table 1: Overall Dam Passage Survival (in percent) – 2010 to 2014

Species	Mean Survival		
	Snake River Dams*	Columbia River Dams	Difference in Survival
Yearling Chinook	98.3	96.2	+2.1
Steelhead	99.1	97.5	+1.6
Sub-Yearling Chinook	94.2	94.9	-0.7

* Mean Survival over Lower Granite, Little Goose, and Monumental Dams; data were not collected at Ice Harbor Dam

Smolt to adult survival rates for Snake River Chinook salmon over time continue to fall well short of objectives provided by the Northwest Power and Conservation Council (i.e., 2 to 6 percent survival). Survival estimates for the 2017 juvenile migration year were at a record low for the 1994 to 2017 time series. The smolt to adult survival rate for the John Day River basin downstream of the Snake River is also at a record low, which continues a dramatic decline that has been observed since 2013 (ISAB 2019).

Given this declining trend throughout much of the Columbia River basin, it is again questions why the CSS Model predicts a 170 percent increase in SARs principally on the basis of breaching the Snake River dams. Would dam breaching actually *reverse* a declining *trend* in SARs that has been occurring since the mid-1990s even as improvements to spill operations have been implemented? It seems more reasonable that such a downward trend would be more attributable to an array of other factors including those occurring in the ocean during this general time period of the decline.

In a review by the Independent Scientific Advisory Board (ISAB), tasked with providing critical scientific reviews of the Comparative Survival Study for the past 10 years, the following findings were highlighted. ISAB (2020) reported that present SARs continue to be low, and there are still substantial questions regarding whether there is enough information to suggest specific changes to hydrosystem operations that alone could improve them—much less predict large increases in SARs. Key outputs of the model such as variability in projected SAR's across years and associated uncertainty for performance measures were not presented. There is little explanation as to why the CSS model generated differences across scenarios, particularly such large increases with the dam breaching alternative (ISAB 2020). The principal issues and concerns raised in the ISAB (2020) review of the CSS model predictions are illustrated in the following summaries on the effects of ocean conditions and climate change on SARs.

4. Ocean Conditions Effect on Survival as a Component of SARs

The CSS model does not factor the large array of variables associated with ocean conditions into its predictions of SARs, thus de-emphasizing the importance of ocean survival on returning adults to the Columbia basin.

While the ocean accounts for the most important source and a wide range of variables that affect mortality in juvenile salmonids, the CSS model neglects to incorporate a spectrum of oceanic environmental parameters. Instead, the model limits parameters that define ocean conditions to just *two* variables without accounting for other key variables affecting SARs predictions, as described in the following peer-reviewed literature:

- Burke et al. (2013) found that the abundance of adult spring Chinook returns were most associated with the composition and abundance of zooplankton and fish prey in the ocean. Large-scale indicators of temperature variability over the spatial scale that salmon occupy during their ocean residence provide a more accurate indicator of adult run size. Large-scale indicators such as ocean and atmospheric conditions and overall growth and feeding were more closely related to determining adult survival than local and regional environmental variables.

- Rechisky et al. (2013) reported that the different ocean migration patterns of different stocks and species of salmonids can explain why annual populations differ from year to year. For example, improved ocean conditions since 1999 have been associated with somewhat higher adult return rates (but still below Northwest Power and Conservation Council goals); however, Snake River spring Chinook SARs remain lower than mid-Columbia stocks. Specific coastal migration patterns are largely genetic among salmon stocks, annually leading fish to poor or more optimal marine areas. Population-specific variables are not represented in the CSS model and could significantly contribute to survival.

- Crozier et al. (2019) found that ocean food webs contrast sharply in cold vs warm years of the PDO cycle and have been documented to create shifts in the food web regime of salmon prey. These have been associated with shifts in adult salmonid population abundance.

Findings from these studies illustrate the complexity of the ocean and the critical role it plays in determining the strength or abundance of salmon runs of various species and stocks. Variables used in the CSS model, however, do not incorporate the complexities of such factors associated with the ocean environment. Studies also illustrate the potential for ocean conditions to exert a substantial degree of variability on adult run size. In chapter 3.5 of the FEIS, however, mean or median effects are emphasized without considering any measures of variability. To address this, the CSS model results should present the range of observed effects to determine if rankings of alternatives change among years.

ISAB (2020) also reports that the discussion of in-river survival should be coupled with ocean survival. For example, under a transit time of 30 days, fish become older and larger by the time they migrate into the ocean. In this case, it's possible much of the "mortality" already has taken place compared to that which might result from a transit time (under barging) of three days when fish arrive at the ocean much sooner with a greater number of the smaller-size smolts dying at sea rather than in-river.

5. Climate Change

With an emphasis placed on in-river survival, the use of historical river flow data, and ignoring an array of important oceanic environmental variables, the CSS model has not accounted for the effects of climate change on future Columbia basin salmon runs.

Closely related to the complexities of environmental ocean conditions that exert an influence on Columbia basin salmonid populations, is the effect of climate change on SARs. NOAA has reported that the world's five warmest years in the 1880 to 2019 record have all occurred since 2015 with nine of the ten warmest years occurring since 2005 (NOAA Climate.gov). This alone suggests that future predictions of SARs based principally on hydrologic conditions would result in excessively high survival predictions. In order to provide the most accurate prediction of future SARs, CSS modelers must properly account for climate change-related variables. In doing so, it will be essential to:

- Conduct a sensitivity analysis that investigates the impacts of climate change. For example, this could be accomplished by using only water-years with similar patterns to those anticipated in the future due to climate change. Would the relative rankings of alternatives, including Alternative MO3, presented in the FEIS change if future climate scenarios are represented in the model analysis?

- Provide a more detailed comparison among different types of flow years. Including such year to year variation in the output measures would better reflect the response to the different Multiple Objective Alternatives.

- Incorporate the relationship of juvenile fish characteristics (e.g., body size, body mass, and condition factor) and date of ocean entry to survival.

- Consider much more thoroughly the variability of ocean conditions and climate change. Caveats that affect the interpretation of findings, particularly those related to predictions of future benefits of alternatives, should be fully presented. For example, flow regimes are likely to look different in the future with climate change. This can affect the maturation of juvenile fish and proportion of adults that survive upriver migration.

- Account for warm water mass phenomena like the "Blob" that have developed in the nearshore Pacific Ocean. More localized, but significant, patterns of environmental factors and food abundance also could have major impacts that are not presently represented in the model.
- Consider the effects of harvest rates and marine mammal predation within the estuary as this is very relevant to the variability of SARs predictions. The SARs predictions do not appear to have been adjusted for oceanic and in-river fisheries or marine mammal predation. These factors affect survival during both the early and late ocean periods rather than the interpretation of changes in the river that might benefit juvenile salmon as the CSS model currently relies on.

6. Conclusions

SARs estimates are one of the most critical parameters developed from the CSS model as reflected in the Northwest Power Conservation Council's use of this metric to assess progress toward regional goals. However, and as noted in the assessment above, a substantial body of evidence exists indicating that breaching four dams on the Snake River, while retaining the operations of four Columbia River dams downriver, does not support predictions of increases of SARs by 150 to 170 percent over the current population levels of Snake River Chinook and steelhead. This is particularly so since the CSS model principally uses in-river flow regimes and their effects on juvenile salmon outmigration ("latent mortality"), while not accounting for other significant variables affecting salmon populations in the ocean (e.g., juvenile fish size/length upon ocean entrance; ocean conditions affected by natural variability and climate change; in-river temperatures; and harvest/predation).

As noted above, recent studies such as Crozier et al. (2019), Burke et al, (2013), Rechisky et al. (2013), and ISAB (2020) show the substantial influence and complexity that large-scale oceanic factors have on salmon survival, particularly in the context and broader influence of climate change. While the CSS model does not currently incorporate most of these factors, it is essential to do so due to their likely effects over and above those influencing in-river juvenile survival.

The other key issue of concern with the CSS model analyses is the treatment of uncertainty when making SAR predictions. Principally, this involves considerations of data availability, interpretation, and the suitability or limited range of variables used in interpreting or developing results. As reported by ISAB (2020), many of the above variables that were not explicitly represented in the model were "black-boxed" in the model based on water transit time, spill over dams, and seasonal effects. Little explanation of model inputs were presented. There is an assumption that a large number of mortality factors are captured in past flow data used in the model and that their relationships will not change in the future. This is likely to induce a substantial bias and overestimation of future survival rates given the lack of environmental factors represented in the model such as in-river temperature effects on juvenile outmigration and temperature effects on ocean conditions and spatial distribution of salmonid food sources.

Until the CSS model addresses uncertainty issues and a broader range of variables, particularly those that represent the impacts of ocean conditions on survival, SAR predictions related to the MO3 Alternative lack the necessary support to substantiate the magnitude of the estimates presented in the FEIS. These high estimates of survival after breaching the Snake River dams are also not supported by actual data that demonstrate rather high survival already exists over those dams. It is also counter-intuitive that such large increases can occur within a regime of declining survival trends over the past two decades when fish have to traverse four additional dams within the Columbia River System. Under these circumstances, the comparatively modest but significant increases found by the LCM model provides a more plausible prediction of future salmon returns.

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Jim Starkes is a senior fisheries scientist with David Evans and Associates, Inc. of Bellevue, Washington. Jim has over 28 years of experience as a fisheries and habitat biologist, evaluating the effects of anthropogenic activities on fish, particularly juvenile salmonids and their habitats in the Pacific Northwest. He has produced numerous environmental assessments, environmental impact statements, and biological assessments in compliance with the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), and Marine Mammal Protection Act (MMPA). Jim's specialty is working with design engineers, regulators, and stakeholders to identify and evaluate potential impacts of development on salmonid habitats and in designing ecologically meaningful restoration measures to off-set such impacts. For the Columbia River System Operations (CRSO) Draft Environmental Impact Statement (DEIS), Jim served as task manager for the initial preparation of the fish sections where he prepared the Existing Environment sections for 21 stocks of anadromous salmon, resident fish, and ESA-listed fish within the Columbia basin.

Mike Wert is a senior fisheries scientist with David Evans and Associates, Inc. of Bellevue, Washington. During his 35-year career, Mike has completed an array of ecological baseline investigations, feasibility studies, NEPA environmental impact assessments, and mitigation plans for water, energy, and transportation projects where he assessed potential effects of infrastructure development on anadromous and resident fish populations in the Pacific Northwest. For the hydroelectric and water supply industries, he has prepared FERC licensing exhibits, conducted anadromous fish research, and evaluated effects on fish passage from proposed or existing projects that involved dams, turbines, spillways, water intakes, fish bypass systems, and culverts. Under contracts with the Electric Power Research Institute (EPRI), he co-authored reports in cooperation with international fish passage experts Milo Bell and George Eicher. The EPRI research involved assessing fish bypass screen technology and factors that contribute to the mortality of fish passing through hydraulic turbines, bypass systems, and spillways based on research performed at hydroelectric facilities on the Columbia River, across the United States, and internationally.