Independent Review Panel Report for the 2016 California WaterFix Aquatic Science Peer Review

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Scope and Purpose of the Review: This report presents the findings of the 2016 California WaterFix Aquatic Science Peer Review. An Independent Review Panel was convened by the Delta Science Program to provide the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and California Department of Fish and Wildlife (CDFW) with an independent scientific evaluation of the methods and approaches for developing the joint Biological Opinion requirements and analyses prepared for the CDFW 2081(b) Incidental Take Permit application for the California WaterFix.

The Panel was charged with reviewing: (1) selected sections of the Biological Assessment (BA) that seeks to predict the effects of the WaterFix project on Endangered Species Act (ESA)-listed species and their designated critical habitats, (2) the draft Analytical Approach to developing the joint Biological Opinion (AABO) and (3) the proposed methods for assessing project effects on Longfin Smelt.

After reviewing a set of documents (Appendix 1), the Panel participated in a public meeting in Sacramento, CA on April 5-6, 2016. On the first day of this meeting, the Panel interacted with agency representatives following their presentations on the three topics above. On day 2, the Panel communicated and discussed its preliminary findings to agency representatives and the public. This report summarizes the Panel's findings and recommendations in full detail.

Executive Summary

The new water dual conveyance facilities proposed as part of the CA WaterFix (WaterFix or CWF) project would create substantial changes in the aquatic environment of the lower San Joaquin and Sacramento Rivers, the Delta, and downstream estuarine areas. The construction and operation of the Waterfix facilities must comply with U.S. Endangered Species Act (ESA) Section 7(a)(2). As part of the ESA consultation, the US Bureau of Reclamation (Reclamation) and the CA Department of Water Resources (DWR) have written an extensive Biological Assessment (BA) that projects the future effects of the new facilities on ESA-listed species and their designated critical habitats. In addition, National Oceanographic Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (FWS) are evaluating the effects of the proposed CWF on listed species and their designated critical habitats and are working towards the development of a joint Biological Opinion (BO). Further assessment under the California Endangered Species Act (CESA) also includes the analytical framework proposed for the incidental take analysis for Longfin Smelt that is listed under CESA.

The Independent Review Panel (Panel) was charged with reviewing sections of the BA, as well as the draft Analytical Approach to developing the BO. The Panel was asked to focus on those BA sections (Appendix 1) that project the future effects of facility construction and the completed, operational project on listed salmonids and smelt species. Potential effects during operation could arise from withdrawals at the new water intakes on the Sacramento River, altered physical structure and water flow patterns at the existing southern Delta pumping facilities, altered spawning and rearing habitat in the rivers, Delta, and estuary, altered river-flow regimes, changing future climate, and other future changes in the aquatic environment. The Panel was charged with evaluating whether the models, analytical methods, and assumptions used in the BA, and their uncertainties, were clearly described and were based on the best available science.

The Panel finds that the best available science was generally used as a basis for the BA's models and analytical methods and that these were adequately described. The Panel also supports the BA's consistent strategy of comparing the projected effects on fish of the Proposed Action (PA) versus a No Action Alternative (NAA), under future scenarios of environmental conditions that were constructed from historical time series and adjusted to include likely trends of climate change.

However, the best available science for the greater Delta area is inhibited by important knowledge gaps and that science often provides only piecemeal and quantitatively uncertain projections of future environmental conditions in the Delta area and of fish responses to those conditions. In this report, the Panel identifies many of these knowledge gaps and uncertainties in the BA, some of which could be addressed during the development of the BO. Most of the gaps, however, can only be addressed by extended future research, monitoring, and adaptive management in construction and operational phases. As a result, a BA written in 2016 cannot realistically reduce the uncertainties of most of its model projections. And, while the BA acknowledges many uncertainties about species response to direct impacts (e.g., entrainment at North Delta Diversions or southern Delta facilities), the systematic and cumulative effects from more indirect sources (e.g., food web, predators) have equally great uncertainties and require more consideration.

The Panel finds that the best available models are currently being used to simulate water transport throughout the Delta and its watershed, with some concern expressed for reliability of these models. However, the Panel had greater concerns about future sediment movement and water quality, and in particular, about whether the North Delta Diversions (NDD) might exacerbate the downstream sediment starvation that is already occurring. The Panel also feels that the BO should consider potential changes to fluvial and tidal fish habitat throughout the Delta and not just near the NDD and southern Delta facilities, due to systematic changes in inundation and salinity that would be caused by PA operations. Finally, the Panel suggests that projected climate change influences should extend beyond 2030, in spite of their significantly greater uncertainties.

The Panel finds that the salmonid survival models are generally adequate, although they do not capture the relative timings of peak flows and outmigration of the more vulnerable life history stages. In addition, possible depensatory mortality is not considered, nor is the cumulative effect, over a sequence of dry years, of predicted greater mortality under the PA, for juvenile Chinook Salmon. The Panel also finds that possible screen-impingement and predation effects on salmonids at the NDD are likely to require targeted adaptive management experimentation. We are also concerned that important changes in location and timing of available rearing and migratory habitat under the PA are not being captured by BA model projections, nor are the effects of the PA on salmonid predators such as Striped Bass. The Panel approves of using the Viable

Salmonid Population framework (McElhany et al. 2000) in the draft AABO. However, the data are limited and the uncertainty is high for applying that framework to Delta salmonids.

The BA analyses for Delta Smelt comprehensively addressed the effects of numerous factors on all life stages. However, as with salmonids, each of the single-factor analyses was independent of the others and no analysis assessed cumulative effects in the context of a full life cycle/population model. The Panel noted the uncertainties surrounding potential beneficial effects of the PA, potential negative effects, and probable neutral effects. The key projected beneficial effects are reduced entrainment at the southern Delta facilities. The BA's considerations of screen impingement effects at the NDD, potential habitat loss, and turbidity reductions were felt to be highly uncertain. In particular, the Panel recommends additional evaluation of PA effects in the Suisun Marsh area which studies have identified as high-abundance Delta Smelt habitat. The Panel also finds high uncertainties about the PA's effects on Delta Smelt's predators and food sources.

The draft Analytical Approach for Longfin Smelt is hampered by little information on Longfin Smelt population dynamics and abundance. The Panel finds that this knowledge gap results in high uncertainty of the BA's comparisons of PA and NAA effects, particularly on Longfin Smelt entrainment at the southern Delta facilities. The BA and the Analytical Approach also employ a particle tracking model (PTM) to estimate the fate of smelt larvae as passive drifters; however, the Panel has highlighted some known concerns about the PTM analyses. Because so little quantitative knowledge exists about the Delta's Longfin Smelt population, the Panel reinforces the BA's emphasis on real-time operational management and monitoring to minimize Longfin Smelt entrainment effects under the PA.

The Panel noted that the BA's quantitative comparisons of PA and NAA effects have two major sources of uncertainty: the uncertainty of future environmental conditions, and the model-prediction uncertainty of how fish will respond to those conditions. Although the BA does a good job of representing the first source, the Panel finds that the BA often understates and misinterprets model-prediction uncertainty. The Panel recommends specific methods to increase the realism of uncertainty estimates and interpretations in the BA. Because high uncertainty is a pervasive issue in the BA comparisons of NAA and PA, the Panel also recommends that the Analytical Approach to the BO should describe how this uncertainty will be formally and quantitatively incorporated into the BO's decision-making process.

The substantial uncertainties of nearly all BA analyses are the dominant theme of the Panel's findings. If the WaterFix project goes forward, the Panel believes that its uncertain impacts on ESA-listed fish species can only be addressed by a vigorous, well-supported, protective program of "active" adaptive management (AM), and by application of the precautionary principle when developing the BO. The Panel articulates this view more fully within the report and outlines the essential components of a successful AM program. The Panel also recommends that the Analytical Approach to the BO describe how the AM design and implementation for WaterFix will be evaluated.

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1. Introduction

1.1 Background

As part of its formal charge, the Panel was given the following background for its review, which we quote in its entirety:

> “The Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR) coordinate the operation of the Central Valley Project (CVP) and the State Water Project (SWP). As part of the California WaterFix (CWF), DWR proposes to construct and operate new water conveyance facilities in the Sacramento–San Joaquin River Delta, including three intakes, two tunnels, associated facilities, and a permanent head of Old River gate; as well as operate existing southern Delta facilities in coordination with these new facilities.
>
> Because the operation of the CVP/SWP is coordinated, Reclamation is the lead agency for the Endangered Species Act (ESA) Section 7 consultation. This consultation is also intended to address consultation with the U.S. Army Corps of Engineers to issue permits pursuant to Rivers and Harbors Act Section 10, Clean Water Act Section 404, and 33 United States Code 408. It is understood that additional consultation on the U.S. Army Corps of Engineers permitting may be required as the CWF is more fully developed.
>
> As noted above, the construction and operation of the new dual conveyance facilities will need to comply with ESA Section 7(a)(2). As part of the CWF ESA consultation, Reclamation and DWR have written a Biological Assessment (BA) that summarizes the effects of the action on ESA-listed species and their designated critical habitats. NOAA’s National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (FWS) are evaluating the effects of the proposed CWF on listed species and their designated critical habitats and are working towards the development of a joint Biological Opinion (BO).

In addition to complying with ESA, DWR intends to obtain California Endangered Species Act (CESA) authorization from the California Department of Fish and Wildlife (CDFW) under Fish and Game Code section 2081(b) for incidental take related to the construction and operation of the CWF and modified operations of the SWP. DWR will submit an application which will include an analysis of the effects of the proposed action on CESA listed species. CDFW will review the CESA-specific analysis of the perceived impacts for state-listed species and may issue a permit if conditions in Fish and Game Code sections 2081(b) and (c) are met.

The purpose of this independent review is to obtain the views of experts not involved in the ESA consultation and 2081(b) permit on the use of the best available scientific information, as it pertains to aquatic ESA and CESA listed species (aquatic species) in the development of the NMFS/FWS BO and the CDFW 2081(b) permit."

End of quote.

1.2 Charge to the Panel, with Panel Responses

In this section, we state the Charge to the Panel, in bold. We also give a brief Panel response, in italics, to each of the specific Charge items. Details of Panel responses are given in Chapter 2.

The Charge was stated as follows:

The Panel will review 1) the draft BO analytical approach (AABO), 2) specific BA analyses (which have been agreed upon by the fisheries agencies and identified in the Panel charge), and 3) the approach to analyzing the effects to Longfin Smelt. Since these items will provide the basis of the joint BO and 2081(b) permit, the review should evaluate whether the items are of sufficient robustness and scientific quality to serve their intended purposes. The Panel members will have at least 30 days to familiarize themselves with the materials. The Panel will

also be given relevant background information to consider and will receive presentations from the relevant agencies at the public meeting.

Specific scientific questions for review of the AABO, specific BA analyses, and Longfin Smelt analytical approach:

<u>BO Analytical Approach</u>

1. **How well is the AABO designed to adequately assess potential responses of the target listed species to the effects of the proposed action (i.e., both direct and indirect effects of the project)? In answering this question, please consider the following:**

How well the analytical approach for salmonids incorporates the Viable Salmonid Populations framework presented in McElhany et al. (2000), "Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units", and aligns with viability assessment approaches in Lindley et al. (2007), "Framework for Assessing Viability of Threatened and Endangered Chinook and steelhead in the Sacramento-San Joaquin Basin".

Panel response: The viable salmonid population (VSP) framework (McElhany et al. 2000) and the manuscript by Lindley et al. (2007) are excellent documents to guide the AABO for salmonids. The AABO is generally patterned on these documents. However, available information is likely insufficient to adequately address all VSP criteria, leading to high uncertainty of the PA effects on species viability. In addition, the AABO needs to heed the uncertainty issues raised by the McElhany et al. (2000) guidelines for the VSP framework.

How effectively conceptual models for target aquatic species are incorporated into the AABO.

Panel response: This could be improved. Several conceptual models are presented in the draft AABO that outline the assessment approach (e.g., Fig. 2-1, 2-2) and show how impacts on individuals can lead to impacts on populations and ESUs. A conceptual *model for factors affecting salmon in the southern Delta was also provided to the Panel (labeled as Fig. 1-4 from an unnamed Bay Delta Conservation Plan (BDCP) document). What is missing is a detailed conceptual model and description of how each ESA-listed species uses the Delta, including factors affecting growth and survival during each life history stage.*

How well the analytical approach for target aquatic species explains how the exposure, response, and risk to listed individuals, populations, and diversity groups resulting from project operations will be assessed, and whether quantitative and qualitative methods and risk assessment tools are used appropriately.

Panel response: The AABO needs to address how its decisions will be made in the face of the high uncertainties in its quantitative projections of PA effects.

Whether the approach for assessing effects provides a scientifically defensible approach for evaluating new adverse effects to aquatic species in the north Delta in addition to any changes in adverse effects at existing south Delta facilities, and what improvements could be made.

Panel response: The BO will draw from the BA projections of new, future adverse effects in the northern Delta due to the PA. These projections do use the best available science. However, the uncertainty of such projections is especially high because there is no local precedent for a project of this type and scale and because existing models of fish response are uncertain. In other words, the best available science regarding northern Delta effects is quite speculative. Because of this uncertainty, we recommend that the AABO describe an approach that includes both active and passive adaptive management.

<u>Supporting Analyses for Target Aquatic Species</u>

2. How complete are the selected target aquatic species analyses in the BA for evaluating the potential effects of the project on the target listed species? In answering this question, please consider the following:

Whether the appropriate analytical tools (i.e., models) were used for the selected analysis and what, if any, additional currently available tools should be used.

Panel response: The BA models represent the 'best science available' for predictive purposes. However, it is widely believed that mechanistic, process-based models, such as life cycle/population dynamics models for fish, are capable of extrapolating biological responses to novel environmental conditions, such as those projected to result from the CWF project. Process-based population models have indeed been developed for ESA-listed fish species in the Bay Delta system. And yet, the BA is unable to use these models, because of their quantitative immaturity and lack of supporting data. Instead the BA relies heavily on simplistic noisy regression models of fish responses, a model structure widely viewed as unreliable for extrapolations. In addition, fish response models are only available for selected ESA-listed species and selected life-history stages. These limitations underscore the Panel's concern with the uncertainties of the BA's projected fish responses to future PA and NAA scenarios.

Whether assumptions are plainly stated and scientifically sound, and whether analytical uncertainties and limitations of methods in the BA aquatic species analyses and Longfin Smelt analytical approach are clearly stated.

Panel response: The assumptions are often clear and sound, but we note several exceptions below. In addition, quantitative uncertainties of fish response models are often understated. As a result, projected similarities of NAA and PA effects are less reliable than they appear.

External forcings of climate and sea level are represented by the central tendency (i.e., the "Q5 climate change scenario") of several climate projections for 2030. Whether the assumptions of that characterization are adequately described in the BA. Note what, if any, additional analyses would help to incorporate effects of climate change.

Panel response: The application of the Q5 scenario is sensible and adequately described. However, the Panel recommends that climate projections be made beyond

2030, because by that time the project will have only recently become operational. We recognize the greater uncertainty of longer-term climate projections, but at least they might suggest whether future conditions will still be within the operating range of current hydrodynamic and fish response models. Furthermore, with increasing climate effects, the magnitude of changes will increase after 2030.

How well the analyses incorporate information from existing synthesis reports (e.g., Management Analysis and Synthesis Team, Long-term Operations Biological Opinions reviews, species recovery plans, 2010 State Water Resources Control Board flow criteria report, etc.) and from responses to recommendations of past independent reviews (e.g., BDCP Effects Analysis review and ICF/DWR responses, etc.)

Panel response: We note that several concerns identified in BDCP reviews (e.g., Parker et al. 2014) have not been resolved by the BA, such as: (1) substantial and understated uncertainties about project effects on ESA species, (2) the lack of an integrated or quantitative assessment of net effects, and (3) the use of "passive learning" instead of a rigorous, institutionalized active and passive adaptive management process.

How adequately the BA analyses and Longfin Smelt analytical approach support a scientifically defensible approach for evaluating new adverse effects to aquatic species in the north Delta, and how adequately they support evaluating any changes in effects at existing south Delta facilities. Note what, if any, additional or alternative analyses are needed. How well the Longfin Smelt analytical approach supports evaluation of combined project operations effects on the target listed species.

Panel response: The best available science is generally used by the BA. However, that science is at best speculative when applied to the magnitude and novelty of change envisioned for the northern Delta. Substantial uncertainties and knowledge gaps remain concerning Longfin Smelt.

1.3 Acknowledgements

The Panel appreciates and acknowledges the substantial effort made by the agency and technical team representative and contractors who prepared the extensive BA and BO documents. We also thank them for their quick responses to Panel requests for additional information. The Panel is also indebted to Cliff Dahm (Lead Scientist), Sam Harader (Program Manager), and the select staff from the Delta Science for their logistical and organizational support. We especially thank Lindsay Correa for patiently addressing our questions about the complex and subtle institutional context of the Bay Delta system, and to Yumiko Henneberry for her rapid and efficient handling of logistics and communications.

2.0 General Comments from the Panel

This section contains detailed comments from the Panel on the Biological Assessment (BA) and on the draft Analytical Approach for the Biological Opinion (AABO). Our comments include specific recommendations to the agencies, labeled ***in bold italics.*** Some of these recommendations could be addressed as part of the BO. However, we recognize that others can only be addressed over a longer term; during planning, construction, and operations of the Proposed Action (PA).

Citations of the form “BA 6-20” refer to page 20 of Chapter 6 of the BA. Likewise, the form “BA A.5.G-30” denotes page 30 of BA Appendix 5.G. Finally, “AABO-40” cites page 40 of the AABO.

2.1 Modeling of Hydrodynamics, Climate Change, and Habitat

The Panel believes that the PA will create more than an incremental change to the Bay Delta system. It will effect major changes in hydrodynamics and associated transport throughout the system downstream of the North Delta Diversion (NDD), with uncertain consequences for fish and their critical habitats. For example, the PA would reduce the Sacramento River sediment load by 10%, and turbidity is known to be a key abiotic habitat factor for Delta Smelt.

In this section, we discuss hydrodynamics, sediment transport, habitat, and climate-change issues of relevance to the PA.

2.1.1 Hydrodynamics

Model output from the water transport models at both the watershed level (CalSim-II) and the Delta level (DSM2) are used as input in many of the other models used in the BA. Therefore, it is important that these models be applied appropriately.

The CalSim-II model is the best tool available for flow-routing optimization because it is specifically designed for the Sacramento and San Joaquin watersheds and incorporates their specific reservoir operating criteria and regulatory restrictions. There is no alternative model that could be considered for this application. During the public portion of the review meeting, the calibration/validation of the CalSim-II model was questioned (Des Jardins 2016). The claims presented to the Panel related to the nuances in the validation process may be valid. However, the details of CalSim-II model calibration and validation are beyond the scope of this Panel’s review. It may be of benefit in the future to have the CalSim-II model verification reviewed by a group such as the California Water and Environmental Modeling Forum.

The DSM2 model is a valid approach to predict salt concentrations in the Delta when large numbers of simulations are necessary, assuming that the bathymetry is not altered from the configuration used in the current calibration and verification of the model. However, there are limitations to how the model results can be interpreted, especially when adding particle tracking simulations. Particle tracking limitations will be discussed in more detail in the Longfin Smelt section of this report (Section 2.4).

The multi-dimensional hydrodynamic models of San Francisco Bay and the Delta are powerful tools that should be used in some cases where the DSM2 has limitations. As an example, it was appropriate to use the UnTRIM model to predict salinity intrusion due to sea-level rise (see section 2.1.4 for more discussion.) Unfortunately, multi-dimensional models take longer to run than the 1-D DSM2 model. In addition, the multi-dimensional models are only available through consultants. Therefore, the use of the multi-dimensional hydrodynamic models is limited even though these types of models are the best available science to address some questions.

2.1.2 Sediment and water quality

Changing the primary point of diversion of water export of the Delta to three inlet facilities in the northern Delta along the Sacramento River rather than from the southern Delta will result in major change in the circulation patterns and associated transport of water and constituents throughout the entire Delta system. Three physical parameters of ecological importance that will be altered are the distribution of sediment, salinity intrusion, and the ratio of source waters (Sacramento vs. San Joaquin) in the central Delta.

The Panel is concerned that NDD operations will increase the sediment starvation that is already occurring in the Delta (Schoellhamer et al. 2013), where approximately two-thirds of the sediment that enters the Delta is deposited in and sustains its marshes, sloughs, and mudflats. More than 80% of this sediment load originates from the Sacramento River, with the remainder from the San Joaquin River (Wright and Schoellhamer 2005). Therefore, it is important to consider not only how much sediment is exported from the Delta as a whole, but also consider whether there are critical habitats in the region of influence of that export site. Based on current water circulation patterns, the suspended sediment in the southern Delta has a low potential of being transported to the Cache Slough complex in the northern Delta, where large wetland restoration projects are being constructed. However, suspended sediment in the Sacramento River, where the proposed north Delta facilities will export water and sediment, is highly likely to be transported to the Cache Slough complex.

BA Appendix 3.B, Conceptual 1 Engineering Report, Volume 1, Section 6.1.2 describes the NDD sedimentation system that is designed to reduce sediment delivery through the dual conveyance system. It cites "normal settling depth and the design WSE depth that will enable sands and coarse silt materials (particle size between 1.75 mm and 0.075 mm) to settle in the basins". However, note that particle sizes 0.075-1.75 mm are usually considered to be all sand, not "coarse silt". Table 6.5 in that document provides estimates of sediment loading to each intake and Table 6.6, showing the river's actual sediment particle distribution, suggests that more than 61% will not settle in the basins. Thus, only about 40% of the sediment load captured by the NDD will be available for “recycling” back into the system, given the caveat that contaminant levels of the retained coarse materials would allow such reuse. Furthermore, the material that will be exported to the southern Delta through the PA’s dual conveyance system will be the fine suspended sediments that provide the greatest benefits through accretion in tidal wetlands, to sustain elevation increases commensurate with sea level rise (Swanson et al. 2015), further starving the northern Delta tidal marsh habitat of juvenile Sacramento Winter-run Chinook Salmon, as well as turbidity, a key abiotic habitat characteristic for Delta Smelt.

One of the key ecological gauges for the Delta is X2. This is the distance in kilometers from the Golden Gate to the 2 ppt isohaline. One of the limitations of this parameter is that it does not accurately communicate salt intrusion once X2 is greater than 81 km. This location (Sacramento River at Collinsville, 81 km upstream of the Golden Gate) is the confluence of the Sacramento and San Joaquin Rivers. For values of X2 greater than 81 km, the parameter really should be reported for each river stem as X2-SAC and X2-SJR because salt intrudes up the Sacramento and San Joaquin stems of the Delta differently depending on magnitude of the flow coming from the San Joaquin and the Sacramento. Therefore, for dry or critically dry conditions with X2 > 81 km, the comparison of X2_SAC and X2_SJR would better report differences salinity intrusion along the Sacramento and San Joaquin stems. For the NAA scenario, the primary water export is on the San Joaquin stem. In contrast, the PA scenario primary exports water from the Sacramento stem.

The Sacramento and San Joaquin Rivers have significantly different water qualities, and the distribution of these sources waters in the central Delta is highly dependent on pumping operations (Monsen et al. 2007). As the system is operated now, the Franks Tract region is currently dominated by Sacramento-sourced water. Mildred Island can be either Sacramento- or San Joaquin-sourced water depending on export pump rates and temporary barrier configuration. With the PA, the likely water source in Franks Tract will likely shift to San Joaquin-dominated water. This shift in water source can be easily simulated with Delta hydrodynamic models.

2.1.3 Habitat

The analytical approach, particularly as expressed in the BA, emphasizes the footprint of the PA installations as the primary areas of Delta habitat changes. However, the BO should apply equal consideration to potential systematic changes to tidal-fluvial inundation and salinity intrusion as a result of the NDD. The BO needs to assure protection and recovery actions for at-risk fish populations throughout the Delta to address indirect effects, such as maintenance and expansion of the fishes' habitats both within the Delta and downstream where salinity intrusion is an important habitat attribute. The only other habitat issue discussed In the BA was the potential inundation of "low floodplain habitat benches" as possible mitigation of fish habitat lost to NDD construction. Yet, the quantity and quality of fish habitat in the Delta and at the transition between the western Delta and upper San Francisco Bay (specifically Suisun Marsh), is fundamentally dependent on Sacramento River inflow that should be considered both under current Delta hydrogeomorphology as well as future conditions above and beyond NDD operations.

Specifically, the BO should provide evidence that NDD planning, operations and adaptive management (AM) monitoring will take into account flooding regimes of both existing and future tidal wetland habitat (e.g., EcoRestore restoration of over 30,000 ac in next five years) and salinity intrusion under predicted climate change scenarios (i.e., sea level rise in the Delta on the order of 43 to 179 cm from 2000 to 2100 (Swanson et al*.* 2015). See also Section 2.1.4 for discussion on the timeframe to consider NDD operations under accelerated sea level rise and other climate factors). Salinity intrusion should also be a primary habitat factor for four fish species of concern—for juvenile Sacramento River Winter-run and Wpring-run Chinook Salmon because their ocean-type life history behavior is usually associated with extensive rearing in oligohaline habitats of the estuary until they have reached smoltification state, and for Delta Smelt and Longfin Smelt because spawning and rearing habitats are suspected to be associated and expanded by extent of X2 positions at the edge of the western Delta.

Hydrodynamic modeling of the broader Delta system's response to NDD should also inform the BO of the effect of the NDD operational (rule-based) scenarios on tidal-fluvial flooding regimes in regions of fish spawning and rearing. For instance, ecological monitoring in the Cache Slough region, and specifically at Liberty Island, indicates that Delta Smelt spawning and rearing may be important in that region. Some of the key questions to ask are: (a) Will the post-PA sediment load at Liberty Island be sufficient for wetland restoration? (b) How will the tidal range change in the region?, and (c) What is the effect of changes in circulation on the beach regions in Liberty Island? Understanding the potential hydrological changes to the flooding regime and salinity intrusion due to the NDD in sensitive seasons of the Delta Smelt life cycle is fundamental to the BO. Furthermore, cumulative changes due to large-scale tidal wetland restoration in that region, which could progressively alter the tidal prism, should be incorporated into that modeling.

Channel junctions that link the Sacramento River to the central Delta should also be considered critical habitat. Currently, the Sacramento River junctions at the Delta Cross Channel and Georgiana Slough are hydrodynamically critical junctions. In current operations, these junctions are located at the transition point between uni-directional flow and bi-directional flow. When the NDD starts operating, this junction area will likely have primarily a tidal bi-directional flow. Therefore, fish will experience this decision point multiple times, which could divert the fish into the central Delta where mortality is likely to be higher.

2.1.4 Modeling Climate Change

Several steps are necessary to incorporate climate change into the hydrologic and hydrodynamic modeling. The charge question only asked about one sub-step, the "Q5 climate change scenario" selection. However, it is important to understand that there is a full suite of inter-related modeling steps that must occur to incorporate climate change.

Step 1 - The BA used a "Q5 climate change scenario" to identify a sub-set of all available General Circulation Models (GCM) to use. The GCM models in this sub-set projected time series of precipitation and temperature at locations throughout the watershed. The Q5 approach achieves the stated goal of capturing the "middle" (median) temperature and precipitation changes, projected by a large number of differing climate projections (Figure 5.A.A.1-1, from A.5.A-788). The Q5 box of selected GCM models captures reasonable middle-of-the-road variation around these medians. The idea of using "averages" from a large number of climate projections is reasonable. It assumes only that the 112 projections, taken as a group, are not biased - that is, that their average does indeed represent something close to what the future will be. The Q5 box defines a Q5 "sub-ensemble" of GCM runs (all the points inside the box). The Panel assumes that all required statistics defining the Q5 scenario (e.g., temperature and precipitation yearly time series) are then derived by averaging the corresponding statistics from only those GCM runs in the Q5 sub-ensemble.

Step 2 - In the BA, sea level is assumed to rise 15 cm at the Golden Gate in 2030. Sea- level rise is expected to alter salinity intrusion into the Delta. As a result, the X2-Flow relationship used in the CalSim-II (watershed flow routing optimization model) for current climate needs to be modified for the 2030 scenario.

Because the DSM2 Delta hydrodynamic model is a 1-D (i.e., channel model) with a seaward boundary at the western end of Suisun Bay, the DSM2 model cannot directly incorporate sea level rise. Instead, the UnTRIM, a commercial 3D hydrodynamic model that has a modeling domain extending from the Golden Gate through the Delta, was used to create datasets to “corroborate” the salinity intrusion results of DSM2 with the UnTRIM simulation results for a 15 cm rise in sea level (BA - A.5.B, Attachment 3). Note that during this modeling exercise, the UnTRIM model was also run to simulate salinity intrusion into the Delta for a range of sea-level rise scenarios. See in particular Figure 5.2-4 (BA - A.5.B, Attachment 2, p. 189).

After the DSM2 model was “corroborated” for 15 cm of sea-level rise, the DSM2 model drove a series of simulations to train an artificial neural net to create a relationship between flow and X2. This resulting flow-X2 relationship is how 15 cm of sea level rise is accounted for in the CalSim-II simulations.

Step 3 - The precipitation time series generated from the Q5 GCM models (Step 1) are downscaled to a regional watershed model. The Variable Infiltration Capacity (VIC) model then creates flow routing inputs for key rivers.

Step 4 - The CaLSim-II optimization operations model is then driven with flow inputs from the key rivers (Step 3), Delta X2-Flow criteria (Step 2), and other reservoir criteria and regulatory restrictions (specified in A.5.a.5).

Finally, the results of the CalSim-II model drive the DSM2 model and other ecosystem/fish models used in the BA.

The Panel recommends that the evaluation of the influence of climate change on the PA operations should be longer than 2030. The Panel recognizes that projections beyond 2030 are subject to rapidly increasing uncertainties. However, projecting only to 2030 does not evaluate how the project will operate under climate change conditions. The 2030 scenario is only just the start of PA operations since construction is expected to take a decade. The Panel also notes the NMFS policy guidance stating that, "When evaluating effects of the action in Sections 7 and 10 decisions, NMFS will use the time period corresponding to the duration of direct and indirect effects of the action" (Sobeck 2016). The NMFS policy also states that "NMFS consultations and permits covering a long time period during which climate change is likely to exacerbate the adverse effects of an action, should incorporate an adaptive approach that includes: adequate monitoring of climate and biological variables; identification of appropriate triggers related to those variables; and identification of protective measures that can be implemented without reinitiating when triggers are reached or, alternatively, triggers then inform the decision to reinitiate."

As was just explained, a significant amount of modeling effort would be required to incorporate climate change for a different time period farther into the future (i.e., 2100) because multiple models would need to be adjusted. This modeling effort would take longer than the projected fast-track revision of the BO technical approach in summer 2016. Therefore, funds and personnel need to be committed to continue to develop these model simulations (e.g., DSM2 "corroboration" with NDD project operations and various levels of sea level rise, training of the artificial neural network model for other future time periods and multiple sea-level rise scenarios) as part of the Adaptive Management (AM) plan.

2.2 Effects on Salmonids

2.2.1 Winter-Run Chinook Spawning, Egg Incubation, and Alevins

The Winter-run Chinook Salmon Evolutionarily significant units (ESU) presently spawns in only one area (below Keswick Dam on the Sacramento River), indicating that the ESU is highly vulnerable to adverse effects (Lindley et al. 2007). The BA concludes that there is potential for changes in reservoir operations, instream flows, and water temperatures in the Sacramento River and American River in response to the PA. However, the BA (BA 5-179) did not describe the management guidelines and actions for these reservoirs that are linked to conditions in the Delta, such that flows released from the reservoirs would be altered in response to the PA. If these actions involve real-time management of the reservoirs, what are the conditions in the Delta that would cause change in water released from the reservoirs?

Sections 3.1.5 and 3.3.3 of the BA describe the real-time decision process, but there is no information to judge how effective this process would be under the PA. Given the lack of information on the real time process, including the effectiveness of current real-time management efforts, the BA did not consider the effects of real time management instead deferring such assessment to the future. The BA says that “the operating criteria will be periodically evaluated and possibly modified through the adaptive management process” (BA 3-97), however, it did not include details about monitoring plans and triggers (see Section 2.6).

We also note that Kneib et al. (2015) recommended development of a much more detailed temperature model for Shasta Reservoir to improve management of cold water releases into the Sacramento River to better support Winter-run Chinook Salmon.

2.2.2 Salmonid Survival Models

Trawl data show that peak catches of juvenile winter-run Chinook Salmon in the lower Sacramento River (Chipps Island and Sherwood Harbor) are closely associated with initial spikes in peak flow at or above 400 m^3 s^{-1} at Wilkins Slough (del Rosario et al. 2013, Israel et al. 2015). Average residence time of juvenile Winter-run Chinook Salmon in the Delta appears to be 41 to 117 days, with longer apparent residence time for juveniles arriving earlier at Knights Landing (del Rosario et al. 2013). Departure date at Chipps Island was fairly consistent across the nine years of investigation (e.g., ~March). Researchers highlight the need for genetic analysis to identify juvenile Winter-, Spring-, and Fall-run Chinook Salmon in the Delta but most studies rely upon non-genetic tools to identify Chinook Evolutionary Significant Units (ESUs). Accurate identification of Winter-, Spring-, Fall-, and Late Fall-run Chinook Salmon emigration through the Delta is critical for evaluating project impacts because the amount of water diverted varies considerably over the juvenile out-migration period (Figure 1, Section 2.2.5). The Panel suggests that genetic identification of Chinook Salmon ESUs could more accurately evaluate habitat utilization and migration patterns of each ESU in the Delta.

The Delta Passage Model, the Interactive Object-oriented Salmon Simulation model (IOS; Cavallo, et al. 2011) , and the Oncorhynchus Bayesian Analysis model for Winter-run Chinook Salmon smolts (OBAN; Hendrix 2008) should consider these findings on migration patterns. In addition, we suggest that the simulated survival estimates from the Perry (2010) model (Figures A.5.D-66 to 70) be double-checked, because we do not find it clear how the weighted, summed survival rates below about 0.10 shown on those plots could have been predicted from a model (Figure A.5.D-65) whose smallest possible predicted values within the 95%CI is about 0.10. Also, OBAN simply examined how the PA would alter water exports at the southern Delta relative to the NAA, while assuming that circulation patterns and physics remain unchanged. However, the PA will also effect major changes in hydrodynamics and transport downstream of the NDD, and these changes should be considered in the model.

The Delta Passage Model assumes a fixed time of entry to the Delta (peaks during mid-January and late February for Winter-run Chinook Salmon) whereas the IOS model allows timing to vary depending on "egg and fry rearing upstream" (BA A.5.D). Assumptions about time of entry of juvenile salmonids to the Delta and residence time in the Delta have important consequences for survival because project operations change month to month depending on the type of water year (Appendix 2). Most of the models do not incorporate the flow/migration timing relationship presented by del Rosario et al. (2013) i.e., the effect of peak flows on movement into the Delta.

The salmon survival models are based on acoustic tagging of large (>140 mm) late fall-run hatchery smolts emigrating through the Delta rather than on smaller fry migrants, parr migrants, and smolts that are produced by winter- and spring-run Chinook Salmon (BA A.5.D - 208). The text did not mention if it incorporated relatively new findings based on smaller Chinook Salmon, e.g., Buchanan et al. (2013: Fall/Spring-run hybrids), Cavallo et al. (2013; 86-121 mm Fall-run Chinook). As noted above, the modeling focus on exceptionally large hatchery smolts leads to considerable uncertainty in how the PA affects other life stages that are critical to the viability of Winter- and Wpring-run Chinook Salmon. Use of the estuarine habitats and residence time will vary considerably with life history stage and species, with smaller, ocean-type life histories demonstrating greater and longer associations of shallow-water habitats in the Delta (e.g., Williams 2006).

The BA suggests that the survival model results for juvenile Winter- and Spring-run Chinook Salmon may be applicable to juvenile steelhead. This assumption in the BA may be too simplistic. Although steelhead smolts emigrate during winter and spring, as do most Chinook Salmon, they may have somewhat different migratory patterns that are not recognized in the BA analyses, including Table 5.4-1(BA 5-71). Steelhead reportedly occur in the Delta from October through July, which spans a longer period than Chinook Salmon. Furthermore, the rate of water diversion from the northern Delta, under the PA, is predicted to be highly variable from month to month depending on type of water year (see Appendix 2). The BA assumption that findings for Chinook Salmon represent PA effects on steelhead further increases the already high uncertainty in PA effects on salmonids.

2.2.3 Density Dependence

The VSP report by McElhany et al. (2000) recognizes the importance of density dependence when evaluating population viability. Compensatory density dependence occurs when there is competition for limited resources as the population grows. For ESA species, this form of density dependence can be very important because it provides population resilience, i.e., productivity (survival) is higher at lower abundances. In contrast, depensatory density dependence is destabilizing and highly undesirable, because lower abundance leads to a higher risk of further declines. For example, depensation may occur when a predator consumes a fixed number of prey such that a higher percentage of the prey population is killed at lower prey abundances.

A misconception is that density dependence is weak among ESA-listed species, whose abundance is low. This was the perception in the Columbia Basin when salmon were initially listed under the ESA. However, a review by the Columbia River Independent Scientific Advisory Board (ISAB 2015) found strong evidence for density dependence in nearly all populations that were examined. Compensatory density dependence was high, in part because habitat quantity and quality had declined and many hatchery spawners supplemented the natural spawning populations. However, depensatory predation was observed in some areas.

A recent review of juvenile salmon foraging performance in estuaries revealed that density dependence was evident in estuaries that have lost wetland habitat (David et al. 2016), suggesting density dependence is likely an important factor in the Delta. High abundances of piscivorous fishes in the Delta, especially non-indigenous species, may contribute to depensatory mortality of ESA species. An important question is whether the PA may enhance abundances of predators that consume ESA-listed fishes.

2.2.3.1 Would the PA Cause Depensatory Mortality?

Examination of juvenile Winter-run Chinook Salmon survival in the Delta, based on the Delta Passage Model, suggests that the PA might cause depensatory mortality, which could destabilize the population. This potential adverse effect was not discussed in the BA but it should be evaluated in the BO, especially given the likelihood for a series of dry years that may help create depensatory mortality.

The BA projected that juvenile Chinook Salmon survival through the Delta under PA conditions would increase by about 80% in higher-flow years, ranging from 0.24 in critically dry years to 0.43 in wet years (BA 5-114). Survival during the PA was projected to be 7% less than that in the NAA during dry years and 2% less during wet years. In the mainstem Sacramento River (where survival tends to be higher), survival during the PA was projected at 8% less than that in the NAA during dry years and 4% less during wet years. In all water years, juvenile Winter-run Chinook Salmon survival was projected to be less during the PA compared with the NAA.

Greater adverse project effects during dry compared with wet water years is an important finding. Juvenile Chinook Salmon abundance entering the Delta is likely much lower during dry compared with wet years (e.g., Israel et al. 2015), and the PA is projected to kill a higher proportion of fish compared with the NAA, especially during dry years. Therefore, the PA appears to have a larger adverse effect during dry years when other factors are also contributing to low survival and abundance of fish entering the Delta. This relationship could have a destabilizing effect on the population depending on the magnitude of the effect.

The Panel recommends evaluation of the compounding effect of the PA and dry years, and the potential for depensatory mortality, using a series of continuous dry years. Drought often occurs for a number of consecutive years, as the recent CA experience confirms, and climate change is likely to produce more frequent drought conditions (Dettinger and Cayan 2014, Romero-Lankao et al. 2014).

2.2.4 Effects at the North Delta Diversions

The Panel found the assumptions and rules about the vulnerability of Winter-run Chinook Salmon to be somewhat unqualified, and requiring more explicit distinction of life history diversity in the BO. It is particularly uncertain whether the ocean-type life history stage of this stock is appropriately addressed in designing the operational rules for NDD, rigorous consideration of northern Delta habitat impacts, or indicators and triggers for NDD impacts.

Whereas the size distributions and seasonal occurrence of Winter-run Chinook Salmon outmigrants is documented to be predominantly as small ("parr") juveniles that enter the northern Delta with early pulsed Sacramento River discharge, the median of the emigration often follows later in December to January in wet and above-normal years (del Rosario et al. 2013). These ocean-type juvenile salmon rear for extensive periods in tidal wetland and peripheral aquatic habitats of the Delta before emigrating to the Bay and ocean (Brandes and McLain 2000, Williams 2006), such that >50% of the cumulative catch emigrating from the Delta (i.e., at Chipps Island) may be up to 3-4 months from the time they entered the Delta (i.e., at Knights Landing), a significant portion thereof spent rearing in the Yolo Bypass in wet years (del Rosario et al. 2013).

The Panel recognizes considerable uncertainty about whether the operational rules for the NDD considered this often protracted demography of the Winter-run Sacramento Chinook migration to the Delta, or about the potential effects of major diversion on their rearing habitats within the Delta. We suggest that avoidance or minimization of deleterious effects to juvenile migrant and rearing Winter-run Chinook Salmon should be based predominantly on detailed real-time monitoring rather than statistical or categorical relationships between flow and fish abundance, preferably within an AM framework that includes active AM.

2.2.4.1 Fish Screen Effects

The BA (Chapter 5 and Appendix 5D) describes some of the characteristics of the northern Delta fish screens, but it does not mention whether or not the screens are designed to meet all of the criteria for salmonids as described by NMFS (2011). The brief analysis examines potential impingement of Salmon assuming an approach velocity of 0.2 ft s^{-1} (i.e., the NOAA criterion), but NMFS (2011) describes a number of additional design criteria needed to protect salmonids. ***The Panel recommends that all fish screen criteria described by NMFS (2011) should be explicitly addressed in the BO.***

Sweeping velocity is discussed in the BA but there are no estimates of sweeping velocity along the river banks now and after construction of the very long fish screens. NOAA criteria recommend sweeping velocities of at least 0.8 ft s^{-1} and sweeping velocity must not decrease along the length of the screen. Will these criteria be met by the PA?

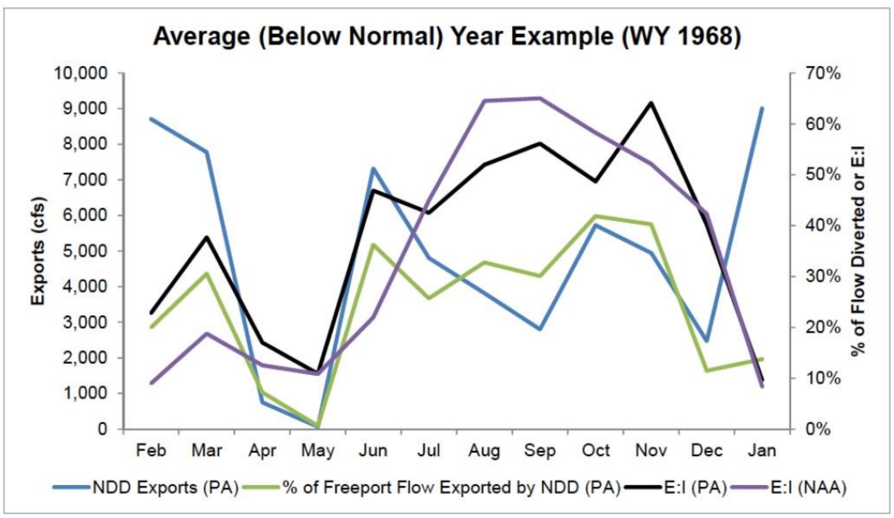
The BA concludes that the effects of NDD on impingement of juvenile salmonids is uncertain and states that this uncertainty would be addressed with monitoring and studies that examine impingement and passage time along the intakes.

2.2.4.2 Predation Effects

The BA provides a reasonable conclusion regarding predation at the northern Delta water intakes: *"Overall, there is potential for predation of juvenile salmonids along the NDD, which would constitute an adverse effect."* (BA 5-84).The BA analysis cites two studies for predation impacts, the field study at Glenn Colusa and a bioenergetic approach. Ultimately, the potential effect is highly uncertain because the predation will depend on local conditions and the responses of the ESA fishes and predators to those conditions. The effect of the NDD facilities and operation on predation at this location will depend on whether the intake structure and operation alter predator abundance at the intakes and whether juvenile fishes aggregate along the screens. Some aggregation of prey fishes is likely since water is drawn into the screens and most fishes are excluded. The BA proposes to reduce predator density at the screens. An experimental approach should be conducted under AM, starting with estimates of predatory fishes at the fish screen locations and experimental control sites prior to construction of the screens. This should be followed with sampling after construction to determine whether predator abundance has increased relative to control sites. Predator diet should also be examined.

2.2.5 Water Diversion Effects on Salmonid Critical Habitat

The proposed seasonal reduction in water discharge though the Delta provides an index for the degree to which critical habitat for ESA-listed salmonids in the Delta will be altered by the PA. Figure 1 shows the percentage of total Sacramento River discharge that is expected to be removed from the northern Delta during an average "below normal" water year. In November, approximately 40% of the Sacramento River water is expected to be diverted by the PA. In November, moderate numbers of adult Winter-run Chinook Salmon, juvenile Winter-run and Spring-run Chinook Salmon, and small numbers of adult steelhead are likely to be present (BA 5, Table 5.4-1). The water removal rate is expected to decline to approximately 10% in December and January when abundance of juvenile Winter- and Spring-run Chinook Salmon increases. However, water removal increases to 20%-30% of the total river discharge in February and March when abundances of adult and juvenile Winter- and Spring-run Chinook Salmon and juvenile steelhead are expected to be relatively high (e.g., Williams 2006, del Rosario et al. 2013). The percentage of river water diverted each month varies considerably with the type of water year (see Appendix 2).



Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment. Note: E:I = exports to inflow ratio; the inflow (I) term for the PA is the Sacramento River downstream of the NDD; NDD exports are not included in the export (E) term for the PA.

Figure 7. Modeled Mean Monthly Exports by the North Delta Diversions and Percentage of Sacramento River at Freeport Flows Represented by these Exports, Water Year 1968.

Figure 1. Reproduction of Figure 7, Appendix 2. Estimated monthly diversion of Sacramento River water at the North Delta Diversions (NDD; blue line) as a percentage of total river discharge just upstream from the intakes (green line) during an average "below normal" water year. See Appendix 2 for additional analyses by water year type.

The quality and quantity of habitats available for Chinook Salmon and steelhead in the Delta depend on inflows from the Sacramento River (del Rosario et al. 2013). Increased flows often provide more rearing habitat and more migratory habitat, suggesting the northern Delta water diversion has the potential to significantly alter habitat availability, and potentially quality, in some months depending on water year. As mentioned previously, salmon fry and parr migrants utilize shallow estuarine habitats more than yearling smolts, which tend to be farther offshore in the current. The effects of water diversion on habitat of salmon fry and parr migrants is complicated by the interactions between river flow, tide stage, salinity, and the locations of existing preferred habitats along the migratory corridor. The interplay among these complex interactions was not assessed in the BA.

The Habitat Suitability section of the BA (BA 5.4.3.1.2.2.1) briefly attempts to examine the effects of water diversion at the northern Delta intakes on water depth characteristics at artificial wetland and riparian benches, although not natural tidal wetlands. This simple approach does not account for observed preferred habitats along the migration corridor and other characteristics noted above. Nevertheless, the BA reported 19% to 29% lower riparian index during the PA compared with the NAA. Inundation of manufactured wetland benches did not differ between the two scenarios because the wetland benches were designed to be covered by water in nearly all water years, suggesting that the wetland depth index was not sensitive to flow conditions and was not a reasonable tool for evaluating project effects. Furthermore, the bench habitats represent only a small fraction of habitat that may be used by juvenile salmon as they rear and move downstream. ***The Panel recommends additional effort to evaluate PA effects on critical salmonid habitats, including natural and restoring tidal wetlands predictably under the large-scale influence of the NDD operations.***

2.2.6 Effects on Salmonid Diversity

McElhany et al. (2000) highlight the importance of maintaining population diversity when evaluating viability, but salmonid diversity is not fully evaluated in the BA. Diversity in the types of salmonid life history patterns (fry, parr, smolt migrants) is discussed above. Here we discuss diversity associated with migration timing. Migration timing is linked to life history types.

Juvenile Winter- and Spring-run Chinook Salmon and steelhead smolts are present in the Delta for up to ten months per year, although residence time is much less for individual fish. According to Table 5.4-1 (BA 5), juveniles from one or more of these three species are present in the Delta for all months except August. Diversity is represented in part by the broad period of juvenile outmigration that helps these species adapt to variable conditions in the ocean that can differentially affect salmonids depending on when they enter the ocean (Johnson 2015). In other words, the tail ends of the migratory periods of each species are important to species viability even though the abundance of the juveniles at the extreme ends of the migration periods is small. ***To further evaluate PA effects on diversity, the Panel recommends evaluating water removal effects (up to ~40% of Sacramento River flow depending on month and water year) during tail end migration periods when juvenile salmonid abundance is low, in addition to when most juveniles are present in the Delta.***

2.2.7 Effects on Species that Interact with ESA-listed species.

NOAA Fisheries embraces ecosystem-based management (http://ecosystems.noaa.gov/), therefore the analytical approach to the BO should consider interactions between the ESA-listed species and other species that may be affected by the PA. Predation is likely a key source of mortality for ESA-listed fishes in the Delta. For example, non-native Striped Bass, a popular sport fish, is a significant predator on juvenile Chinook Salmon in the Delta (Lindley and Mohr 2003) and reduced flow may increase predation on salmon (Cavallo et al. 2013). Lindley and Mohr (2003) reported that entrainment at the southern Delta water diversion facilities and ecosystem changes have reduced the carrying capacity for subyearling Striped Bass, and have contributed to their decline from the 1960s to 1996. However, this trend could be altered if the PA does indeed reduce entrainment at the southern Delta facilities. ***Therefore, the Panel recommends evaluating the extent to which the PA may alter the abundance of Striped Bass and other predators that consume ESA-listed species.***

The BA states that Killer Whales ("Orca") would likely depend more on the relatively abundant hatchery Fall-run Chinook Salmon than the wild Fall-run or the ESA-listed Winter- and Wpring-run Chinook Salmon. According to the BA, approximately 20% to 60% of the hatchery Chinook Salmon have been released below the Delta where project effects would likely be minimal. Wild Fall-run Chinook Salmon reportedly represent only ~10% of all Fall-run Chinook Salmon harvested in the ocean fishery, indicating the wild component (which will be influenced by the project) is a small proportion of the total Fall-run Chinook Salmon.

Nevertheless, PA effects on wild Fall-run Chinook Salmon, an ESA candidate species, should be considered because some may be consumed by Killer Whales. This analysis should examine how the PA differentially affects fry migrants and parr migrants compared with smolt migrants, given that large smolt migrants have been the subject of most investigations. Fry migrants and parr migrants are known to represent a significant portion of wild Fall-run Chinook Salmon (Miller et al. 2010, Sturrock et al. 2015), and it is likely that they may be more vulnerable to water removal in the northern Delta compared with smolt migrants. Timing of juvenile migration through the Delta and habitat requirements are likely to be different than smolts, indicating that the PA may have a different effect on fry and parr migrants compared with smolt migrants***. When evaluating the effects of the PA on Killer Whales, the Panel recommends evaluation of PA effects on wild fry, parr and smolt migrants, given that Fall-run Chinook Salmon are likely an important prey of Killer Whales.***

2.2.8 Applying the Viable Salmonid Population (VSP) Framework in the BO

The Viable Salmonid Population (VSP) framework (McElhany et al. 2000) and the manuscript by Lindley et al. (2007) are excellent documents to guide the analytical approach for salmonids. The Analytical Approach for the BO (AABO) also identifies the 2014 NMFS recovery plan for listed Central Valley Chinook Salmon and steelhead as an example of best scientific and commercially available data. VSP criteria include population abundance, productivity, diversity, and population spatial structure.

Although the AABO highlights the use of these approaches for evaluating the viability of salmonid populations, it does not describe the significant limitations of available data needed to apply these approaches when evaluating project effects. For example, a VSP approach should consider how the project might affect diversity and the spatial structure of the Evolutionarily Significant Units (ESU) and Distinct Population Segments (DPS). There are five populations of Spring-run Chinook Salmon, one Winter-run Chinook Salmon population, and four populations of steelhead remaining in the Central Valley. Each of the Chinook Salmon populations likely has multiple juvenile life history strategies. For example, based on otolith analysis of adult salmon, Sacramento Fall-run Chinook (non-listed) were shown to produce considerable proportions of fry migrants and sub-yearling parr migrants in addition to yearling smolts (Miller et al. 2010, Sturrock et al. 2015). Although Winter- and Spring-run Chinook Salmon may produce fewer fry and parr migrants compared with Fall-run Chinook, research on life history types of Winter and Spring-run Chinook is ongoing and will help identify the contributions of these life history types (R. Johnson, NOAA Fisheries, personal communication). Williams (2006) summarizes genetic analyses that differentiate Chinook Salmon ESUs by size. ***The Panel recommends that the AABO describe how it will evaluate project effects on diversity and spatial structure.***

Evaluation of project effects on individual populations and life history types is difficult and this will lead to high uncertainty in the effects analysis. A key question is, to what degree will the PA affect fry and parr emigrants compared with large smolt emigrants (the life history type primarily evaluated in the BA)? The salmon survival models used in the BA primarily rely on acoustic tagging of large (>140 mm) hatchery Late fall-run Chinook and apply these findings to the evaluation of Winter- and Spring-run Chinook Salmon, which include juveniles that are much smaller than these tagged smolts, and to steelhead smolts. Sub-yearling fry and parr are known to rear in the estuary for longer periods of time than smolts. Seasonal use of the estuary also varies with species and life history type, and water removal by the project will vary with season. It is likely that smaller salmonids, which reside in the estuary for longer periods of time, are more vulnerable to reduced flows and related mortality factors (i.e., predators) than larger smolts (e.g., Cavallo et al. 2013), suggesting different effects on each life stage. The effect of reduced flows on residence time of each life history type and their migration route through the Delta is a key unknown because studies have focused on large hatchery smolts and because fish entering the interior Delta have greater mortality (e.g., Perry et al. 2013, Steel et al. 2013, Buchanan et al. 2013).

In short, the data are limited and the uncertainty is high, for applying VSP criteria to ESA-listed salmonids in the Delta. As we also note elsewhere, in such situations McElhany et al. (2000) recommend use of the precautionary principle and AM. ***The Panel recommends that approaches for using precaution and AM be described in the AABO.***

2.2.9 Increased Uncertainty When Using Surrogate Species

When discussing the availability of data, the draft AABO (p. 8) states *"Various sets of data and modeling efforts are useful to consider when evaluating the transition rates between life stages and consequences on population growth as a result of variations in those rates. These data are not available for all species considered in this opinion; however, data from surrogate species may be available for inference."* The AABO does not identify specific surrogate species or how it will determine the suitability of surrogate species for assessing incidental take, but it does reference the final rule describing the use of surrogates in Incidental Take Statements (80 FR 26832, May 11, 2015).

The use of surrogate species introduces additional uncertainty in the assessment of project effects on the ESA-listed species. Studies on the use of surrogate species have recognized this enhanced uncertainty and have emphasized the need to validate the use of surrogate species (e.g., Murphy et al. 2011). We anticipate that the draft BO will provide appropriate justification for the use of surrogate species.

The use of one life stage as a surrogate for other life stages having few data also requires greater discussion and justification. For example, most data for estimating survival of juvenile salmonids through the Delta involve large hatchery yearling Late fall-run smolts (>140 mm). These fish are not likely representative of smaller wild salmon smolts, and other emigrating life stages such as sub-yearling parr migrants and fry migrants that use estuarine habitats differently and for longer periods of time than large hatchery smolts (e.g., Williams 2006).

2.3 Effects on Delta Smelt

The BA for Delta Smelt assessed individual- and population-level impacts in a hierarchical structure that included assessments for each life stage (eggs/embryos, larvae/young juveniles, juveniles, migrating adults, spawning adults) in relation to the PA's construction and operation. The list of BA assessments was comprehensive and included the effects of impingement/entrainment, predation, turbidity, loss of suspended sediment/spawning substrate, contaminants, underwater noise, fish stranding, direct physical injury (from falling riprap, impingement on sheetpiles, entrainment by dredges, or from being struck by propellers), mitigation of harmful *Microcystis* (cyanobacteria) blooms, loss of phytoplankton within exported water, vegetation control, dredging, repair activities, habitat change, gate operations, loss of habitat at the construction site and barge landing areas, and cumulative changes.

The BA did not employ existing population/life-cycle models for the Delta Smelt (Maunder and Deriso 2011, Rose et al. 2013a,b) due to lack of information for properly parameterizing the models (M. Greenwood, April 5, 2016 public meeting). Moreover, the decision to not use these models is supported by Reed et al. (2014, p. 34), who stated "Mechanistic modeling exercises (e.g., Rose et al. 2013a) may help improve understanding of cause-effect mechanisms and help guide future research and monitoring; however, they are rarely sufficient to exclude the need for large-scale experimentation to separate confounding factors, and are not currently suitable for use as management tools."

During the course of the hierarchical assessment of the above-listed potential impacts, the BA generated estimates of uncertainty or otherwise communicated awareness of considerable uncertainties that were associated with individual assessments. Upon reviewing these assessments, the Panel independently noted uncertainties that were associated with potentially beneficial impacts (positive impacts), potentially negative impacts, and relatively neutral impacts. In most cases, the BA recognized and acknowledged the same uncertainties as the Panel did. We discuss the most notable types of uncertainty in the subsequent sections, which are followed by a comparison of the approaches taken by the BA and the conceptual model for Delta Smelt (MAST 2015), and then provide observations on AM of Delta Smelt, including a list of concepts for new data collections that could reduce uncertainty or improve the conceptual model for Delta Smelt.

2.3.1 Uncertainties Associated with Positive Impacts on Delta Smelt

There were some assessments that could not fully capture potentially positive aspects of the PA due to uncertainty. Some of these shortcomings involved computational issues, such as noting that assessments of impacts at the Head of Old River (HOR) gate did not include real-time gate operations that could be actively managed to reduce negative impacts. Others involved larger issues such as entrainment, food-web interactions, and the control of toxic *Microcystis* blooms. Reduced predation at the southern Delta diversions (SDD) is another potentially positive outcome of the PA. Effects of the PA on predation risks are inherently difficult to predict, and are discussed separately along with other issues that relate to potential changes in the Bay Delta's food web.

The BA used similar approaches to assess entrainment at both the NDD and SDD, employing data and relationships that were specific to each diversion location. Accordingly, the BA noted that adult Delta Smelt entrainment risk at the SDD could not be directly modeled due to lack of relevant data for abundance and turbidity. Thus, the BA obtained alternative entrainment estimates from a regression model (USFWS 2008) as predicted from modeled Old and Middle Rivers (OMR) flow that was derived using CalSim-II. These predictions suggested a reduction in adult entrainment at the SDD under the PA with the high uncertainty of the estimates acknowledged by the BA's authors (this regression model had $r^2 = 0.36$, exemplifying the "weak" models discussed in Section 2.5.2). The BA also noted the prospect of an overall increase in the Delta Smelt spawning-stock biomass as a beneficial result of reduced adult entrainment at the SDD under the PA. This potentially positive impact on the spawning stock appears reasonable but remains uncertain.

Various other mathematical approaches were applied to the prediction of entrainment risks for other life stages. In general, the entrainment modeling was afforded a great deal of effort with appropriate rigor applied when possible. Some of these efforts yielded inherently uncertain results due to limitations of the models used (e.g., poor regression fits/wide confidence limits around predictions, and the use of the DSM2 particle-tracking model without including real-time withdrawal management); as mentioned, these uncertainties were acknowledged by the BA's authors. Under many scenarios (month-year type combinations), estimates of larval entrainment were reduced under the PA, although there were also many scenarios where larval entrainment at the SDD was similar between the PA and the NAA. It should be noted that these modeling exercises were conducted in the absence of actual larval entrainment histories; most SDD entrainment involves larvae, which have not been monitored at the SDD (Kimmerer 2008). The general conclusion for entrainment at the SDD was positive, indicating salvage and population losses would decrease under the PA except during drier years, when northern Delta diversions would be small. Figure 6.1-9 in the BA compares estimates of entrainment reduction among year types, including graphical depictions of uncertainty.

The BA also considered the loss of phytoplankton within the exported water at the NDD, recognizing that the phytoplankton within Delta inflows contributes to the foundation of the Delta's aquatic food web. The BA estimated mean phytoplankton biomass diversions at the NDD would range 0-12% (minimum 5^{th} to maximum 95^{th} monthly percentile) and would rarely exceed a relatively low value of 5% of the Delta's standing stock of phytoplankton during any given month. However, the BA points out that the southern Delta is generally more productive than the northern Delta, and if southern Delta pumping becomes reduced under the PA, then phytoplankton production south of the Delta could be retained within the Delta as a whole, possibly yielding a net benefit to Delta secondary productivity, including productivity of Delta Smelt (BA 6-133). A more quantitative assessment of this apparent net benefit would be difficult, as it would be impeded by the limited quality and quantity of data related to phytoplankton biomass and productivity near the SDD (M. Greenwood, April 5, 2016 public meeting). While there is considerable uncertainty in this conclusion, the position of the BA on this issue appears to be reasonable.

The BA suggests that the distribution of pumping between the NDD and SDD can be manipulated to reduce water-residence times in areas of the Delta where toxic *Microcystis* blooms form (BA 6 -172). This is a suggestion for ameliorating a current problem but there is no evidence that it will actually be successful.

2.3.2 Uncertainties about Negative and Neutral Impacts on Delta Smelt

Life-stage-specific impacts of construction and maintenance of the NDD, HOR gate, barge landing sites, and new Clifton Court Forebay facilities (construction, maintenance dredging, mechanical and electrical repairs, riprap replacement, vegetation control, etc.) were largely based on the extent of spatio-temporal exclusion between Delta Smelt distributions and these various PA activities. In other words, substantial impacts were not expected to occur whenever particular life stages, which have seasonally specific geographic distributions, were expected to be distributed far enough away from PA activities. Initially, this approach appears to be sound, yet it is flawed by logical circularity. In effect, the approach first assumes that the historical status quo represents the future condition—despite the imminence of substantial future change - and then uses this position to maintain that the future change will result in the historical status quo. Future change is potentially large, as the PA could result in >35% maximum diversions of Sacramento River flows during all except critically dry years (BA 6-69). The BA does not recognize the uncertainty in its assumption that future Delta Smelt distributions will be the same as those in the past. It should be noted, however, that the BA's claim that few adult Delta Smelt would be expected near construction sites (i.e., during the time period of construction) is reasonable because it applies to a time period that precedes the PA's export of water from the Sacramento River. That is, it is not subject to the above-mentioned flaw in the spatio-temporal exclusion approach.

The assessment of impacts of water-facility operations included both modeling and spatio-temporal exclusion considerations of life-stage-specific, individual- and population-level assessments for impingement and entrainment at the NDD. Delta Smelt >90 days old (>20-21 mm) were not believed to have strong, future screen-impingement risks at the NDD because they have historically occurred downstream of the three diversion points. The BA acknowledges that any individual juvenile or adult fish that might occur near the NDD diversion points could be more vulnerable to impingement if they were to swim near the shoreline to avoid strong currents in the channel, thus causing them to swim closer to the diversion screens. The BA's evaluation of tidally assisted upstream movement by adults ("tidal surfing") identified this process as being limited to areas downstream of the NDD (i.e., limited by the upstream extent of sufficient tidal transport) and so the BA indicated most individuals would occur downstream of the diversion areas, resulting in a low population-level impact. However, future sea-level increases, combined with reduced river flows under the PA, may confound this aspect of the assessment by increasing the upstream influence of the tides (although concomitant changes to the Delta ecosystem would present a host of other challenges to ecosystem management by the time sea-level rise caused this to become a concern).

While it is understood that critical habitat effects are an element of adverse modification, it is also understood that fish responses to habitat changes may have large uncertainties. Uncertainties associated with future environmental conditions—even those involving relatively simple, abiotic conditions such as turbidity—are acknowledged in the BA. The BA's assessment of habitat impacts started with two abiotic habitat factors, salinity and turbidity, which had been combined by Feyrer et al. (2011) into an abiotic habitat index that can be modeled as a response to X2. The BA for Delta Smelt considered this model (details on BA 6.A-33) but also noted two concerns raised by an NRC review panel (NRC 2010), specifically that the Delta Smelt population response to X2 is statistically weak in both an empirical sense (i.e., in regard to data relationships) and due to the compounded uncertainty caused by linking two statistical models together. These observations undermine the rigor of the abiotic modeling exercise, as acknowledged by the BA's authors.

Another potentially negative impact that has great uncertainty involves turbidity. Delta Smelt abundance tends to be highest at turbidity levels in the range of 1-50 NTU. Turbidity in the Delta is influenced by river-borne loadings of suspended organic and inorganic particles, by local (within-Delta) production of living and nonliving organic particles, and by the transport and re-suspension of these materials by river flows, tides, winds, and three-dimensional density discontinuities within the water column. Given this complexity, there is no comprehensive turbidity model for the Delta. The BA notes that turbidity is difficult to forecast at the SDD, and therefore so is the Delta Smelt's generally positive response to turbidity.

A closely related concern—one that makes the preceding paragraph part of the negative uncertainty discussion— is the Grossman et al. (2013) finding that "Sediment concentrations in the Sacramento River have decreased by half from 1957-2001 and total suspended solids have decreased 50% from 1975-1995 (Schoellhamer et al. 2013)." The PA is expected to result in an additional 10% reduction in the Sacramento River suspended sediment load, which is substantial given the Delta Smelt's widely accepted relationship with turbidity (Feyrer et al. 2007, Sommer and Mejia 2013). Primarily sand-sized particles will be retained at the NDD facilities, but particles of this size are not important contributors to turbidity, and so plans to re-introduce sediments retained at the NDD back into the Delta (BA 6 -172) are not relevant to restoration of lost turbidity. Instead, the finer sediments (those finer than sand) will be removed while in suspension within the exported water, but may possibly settle out of suspension as velocities decrease upon the diverted water's entry into the Clifton Court Forebay. Re-introduction of sand back into the Delta may, however, be relevant to preserving spawning habitat, which is believed to be shallow, sandy, freshwater habitats (BA 6 -171).

BA assessments of population-level effects associated with the operation of Delta water-distribution systems (Delta Cross Channel, Suisun Marsh facilities, North Bay Aqueduct, other facilities) indicate that impacts should be similar or would not differ between the PA and NAA. It would first appear that impacts from continued operation of these systems would be largely secondary to impacts from the dual-conveyance facilities, yet the Suisun Marsh facilities are closely proximal to the area of highest abundance for sub-adult Delta Smelt, as indicated by the Fall Midwater Trawl Survey (Bever et al. 2016). This area of abundance extends from Suisun Slough through Grizzly Bay, Honker Bay and eastward into the area near the confluence of the Sacramento and San Joaquin Rivers, including Montezuma Slough. Any assumptions that Delta Smelt distributions will remain unchanged in this area under the PA should be avoided, and the effects of the Suisun Marsh water-distribution system on Delta Smelt need to be carefully monitored.

2.3.3 Uncertainties about Predation and Other Food-web Relationships Involving Delta Smelt.

The issue of relative predation risk is one of the most difficult challenges to the assessment, as indicated in the report by Grossman et al. (2013), who noted "stress caused by harsh environmental conditions or toxicants will render fish more susceptible to all sources of mortality including predation, disease or physiological stress." This observation was echoed in the Interagency Ecological Program (IEP) Management Analysis and Synthesis Team (MAST) conceptual model (MAST 2015) as "prey may be more susceptible to predation if they are weakened by disease, contaminants, poor water quality, or starvation." Thus, while predators are sometimes conspicuously attracted to elevated prey concentrations (e.g., near the SDD), diffuse predation mortality can also add up to large total mortality losses when factored across larger expanses of habitat, and such losses may be rooted in indirect habitat effects. In other words, predation may be the immediate cause of mortality for individuals that had already been weakened by other environmental conditions or disease. In fish, it is generally accepted that fast growth equates to lowered mortality risk and greater lifetime reproductive potential.

While it is a good idea to reduce Delta Smelt aggregations in areas where there is intense predation pressure, it should also be borne in mind that predation is not likely to be the single cause of long-term declining trends. The MAST conceptual model for Delta Smelt (MAST 2015) recognizes this, stating "Since predation is a natural part of functional aquatic ecosystems, predators are likely not responsible for long-term declines in populations of prey fishes, such as Delta Smelt, without some additional sources of stress that disrupt the predator-prey relationship (Nobriga et al. 2013)."

Prey relationships are also central to survival. The BA for Delta Smelt appears to under-emphasize this importance stating (6A-32): "The abiotic habitat index is based on the probability of presence of Delta Smelt given certain water clarity and salinity and does not explicitly account for other abiotic (e.g., water velocity, depth) and biotic (e.g., food density) factors that may interact with water clarity and salinity to influence the probability of occurrence. However, Delta outflow and its effects on X2 are habitat elements that the projects can directly influence, whereas the other habitat features are not." By implying that the PA would not have an effect on food density, the BA's position becomes misleading. The assumption that the abundance and distribution of estuarine prey organisms will not respond to altered freshwater inflows is not supported (e.g., Flannery et al. 2002, Peebles 2005, Peterson 2003, and references cited therein). Even if X2 is kept the same, interaction between river flows and Delta geomorphology/hydraulics will be different between the PA and NAA, and an associated change in the distribution and abundance of prey should be anticipated rather than dismissed.

In a demonstration of the practical utility of their conceptual model, the MAST group asked why 2011 was a good year for Delta Smelt, and was able to infer good food availability during 2011 (an isolated wet year) as a contributor to the success of all life stages (MAST 2015). The authors also identified the lack of sufficient spatio-temporal data on prey abundance as a major information gap in understanding Delta Smelt abundance trends.

Declining turbidity is one well-documented, long-term trend in the Bay Delta estuary that is likely to have affected prey distribution and abundance. Turbidity has declined markedly at a decadal scale (Schoellhamer et al. 2013), and as a result more light can reach the bottom and submerged plants. Improvements to the light environment, such as this, have been associated with abrupt community change in favor of benthic organisms over planktonic/pelagic ones (Burghart et al. 2013 and references cited therein). In reference to Delta Smelt, MAST (2015) observed “The large proportion of benthic amphipods, cumaceans, and some cladocerans (*Camptocercus* spp.) in the diet is a notable change from Delta Smelt diet in the 1970s. Delta Smelt diets historically did include amphipods, notably *Corophium* spp. (Moyle et al. 1992), yet it was a small fraction of a mostly pelagic based diet. The considerable use of benthic invertebrates for food in recent years is believed to be in large part due to food limitation associated with the long-term decline and changes in composition of the pelagic food web (Slater and Baxter 2014).” The decadal-scale decline in copepods, which are important planktonic prey for multiple life stages of Delta Smelt, is described by Winder and Jassby (2011). Food limitation is now recognized as a principal stressor on Delta Smelt, as discussed by Sommer and Meija (2013). A more comprehensive description of these food-web alterations over time is provided by Durand (2015).

The Delta Smelt is positioned toward the bottom of the food web, where variations in biomass pathways (benthic vs. planktonic/pelagic) often have their greatest effect. There are exceptions to this trend, however. Threadfin Shad, for example, are positioned at a relatively low position within the food web, yet they are capable of regularly switching between planktonic and benthic feeding (Haskell 1959). Predators such as Striped Bass that are positioned higher in the food web often integrate secondary production (prey) from whichever biomass pathway happens to be productive at the time, and as a result tend to be less vulnerable to changes in the relative dominance of one biomass pathway over another (Vander Zanden and Vadeboncoeur 2002, Rooney et al. 2006).

The nature of the Sacramento-San Joaquin estuary's changing aquatic food web has been the subject of considerable debate and discussion, which has resulted in a number of publications related to the decline of the Delta Smelt and other pelagic organisms since 2002 (Sommer et al. 2007). There are differing opinions on the cause of these declines, which translates into yet another form of uncertainty in the assessment of the PA's impacts.

2.3.4 Differences between the BA and the MAST conceptual model for Delta Smelt

Questions regarding whether the best available science was used in preparing the BA invite comparison between the approach taken by resource managers and the approach taken by researchers who use conceptual models to organize their studies. The most fundamental difference between the BA and the MAST (2015) conceptual model is that the BA, out of necessity, is dependent on defendable statistical relationships, models, computations, and direct interpretations of survey data in order to evaluate potential impacts. On the other hand, conceptual models may be largely based on similar types of information, but are allowed to extend beyond the limitations of defendability in order to continually organize the growing repository of synthesized concepts and inferred conclusions that are obtained from the literature and from discussions with other scientists. Conceptual models are more likely to use a weight-of-evidence approach that might be harder to defend (in a legal sense) than a straightforward statistical relationship might be, for example. Both approaches readily recognize where their respective uncertainties lie.

Of the two approaches, the conceptual model is much more process-based and explanatory, and is specifically geared towards facilitation of hypothesis development and testing. In their review of a draft version of the MAST conceptual model, Reed et al. (2012) recommended "The conceptual model in written and schematic form should continue to emphasize processes and their interactions over simple correlations, should ensure Delta Smelt vital rates remain central to thinking, and should be designed for routine use by scientists as an organizational tool and for testing hypotheses associated with the AMP [adaptive management plan].” The emphasis on “vital rates” refers to growth, reproductive, and mortality rates, which determine the likelihood and magnitude of the present generation’s contribution to future generations (i.e., what biologists call “fitness”). Relating habitat effects to fitness completes the argument for relevance within a scientific sense, if not a legal one (i.e., it addresses scientists’ question “why is the relationship you are studying important?”) In practice, various metrics that represent individual health or condition, such as instantaneous growth rate, size-at-age, or the extent of fat stores, can be used as proxies for vital rates that are difficult to measure directly. Again, this is based on the idea that a healthy, fast-growing fish is more likely to have reduced mortality risk and increased lifetime reproductive potential than an unhealthy, slow-growing one. The BA is thus more likely to value abundance-correlated habitat variables as potential statistical predictors of Delta Smelt abundance, and the conceptual model is more likely to value these variables as representatives of habitat processes that affect vital rates. In the latter case, the conceptual model serves as an organized platform from which hypotheses can be developed and tested with the purpose of identifying the habitat processes that most strongly influence vital rates.

Fish habitat includes both stationary habitat (marshes, mudflats, channels, etc.) and dynamic habitat (changing distributions of currents, water quality, predators, prey, competing species, etc.) that are constantly interacting with each other to influence fish vital rates. The fittest fish will be those that occupy habitats where growth is fast and mortality risk is low, but because feeding needs and predation risks typically change as fish grow larger, it is common for fish to occupy different habitats during different life stages or for fish to migrate seasonally. Fish such as Delta Smelt may also respond quickly to short-term (dynamic) changes in habitat quality. In recognition that some processes within the myriad stationary-dynamic habitat interactions are more direct in influencing vital rates than others, the MAST (2015) conceptual model states “The interplay between stationary and dynamic habitat components also helps explain the distribution and movement of Delta Smelt across its range, which cannot be understood —or managed— based on geography alone.”

Conceptual models are intentionally flexible and are allowed to change as new information is obtained and assimilated. Since publication of the MAST (2015) conceptual model, Bever et al. (2016) have identified slow current speed as a third abiotic habitat factor that is positively associated with Delta Smelt abundance. While current speed may not be as predictively powerful as salinity and turbidity, the Delta

Smelt's positive association with slow current speeds is consistent with the Sommer and Maija (2013) position that the availability of zooplankton prey may be limiting Delta Smelt abundance, and that longer hydrodynamic residence times reduce washout and dilution of the zooplankton prey. They state "In general, phytoplankton and zooplankton levels are higher in small channels that are surrounded by dense emergent vegetation in Suisun Marsh (Rob Schroeter, U.C. Davis, unpublished data). This may be more a function of longer water residence time in these low-order channels..." In general, much of the area identified as having the highest abundance of sub-adult Delta Smelt is away from the estuary's primary conveying channel (i.e., high abundance is in the area from Suisun Slough through Grizzly Bay and Honker Bay, plus Montezuma Slough, Bever et al. 2016, Figs. 4 and 12). During low-flow periods, areas near the Sacramento-San Joaquin confluence may also have longer residence times. Sommer and Maija (2013) also suspected that prey export from adjacent marshes subsidizes Delta Smelt prey availability. The BA did not consider zooplankton retention effects, but if the viewpoints of Sommer and Maija (2013) are considered to be part of the still-evolving conceptual model, then zooplankton production and retention is a concern that should be carefully evaluated. When considered from this perspective alone, the PA could have a positive, negative, or neutral effect on Delta Smelt abundance.

For these reasons, the Panel recommends that the abiotic habitat effects of the PA be explicitly considered within the context of the new Bever et al. (2016) findings, while recognizing that this exercise cannot include turbidity due to lack of a turbidity model for the PA simulation (i.e., the abiotic station index of Bever et al. 2016 should be modified to include salinity and current speed, but not turbidity). We also recommend that the water-distribution system within Suisun Marsh be qualitatively assessed for its potential influence on the salinity, current speed, and turbidity within the high-abundance area for Delta Smelt, as described above and as identified in Figure 2. The Panel is referring to the latter assessment as "qualitative" in recognition of the difficulty of mathematically scaling the fine-scale water-management actions within Suisun Marsh to larger spatial and temporal effects within the high-abundance area.

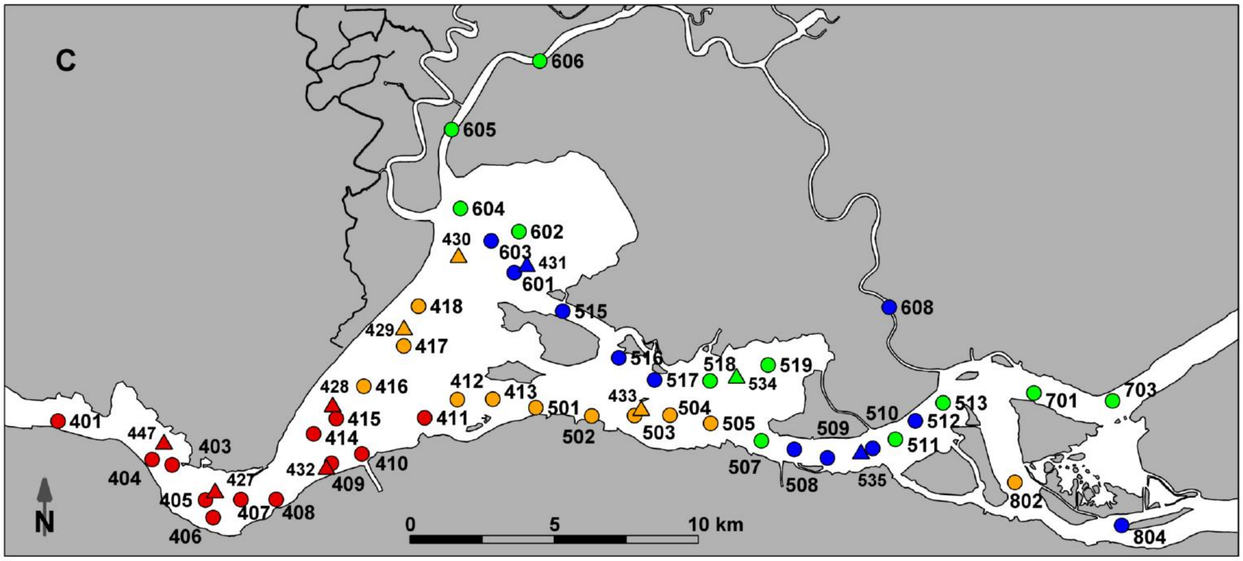


Figure 2. Reproduction of Figure 4C from Bever et al. (2016), indicating station indices for Delta Smelt catch from the Fall Midwater Trawl Survey. Relative Delta Smelt abundance is color-coded among stations in the highest abundance quartile (green), second highest quartile (blue), third highest quartile (yellow), and lowest quartile (red)—the highest historical abundances (1967-2012) were at stations coded green and blue.

2.3.5 Observations on Delta Smelt Adaptive Management (AM)

First, it should be recognized that the group of people with the most comprehensive insight into Delta Smelt biology is the Management, Analysis, and Synthesis Team (MAST) group of the IEP. As a team, they know more about Delta Smelt than the present Panel members do, and they are highly capable of forging ahead and setting new standards for best available science. In order for AM of Delta Smelt to be effective, the MAST team needs to be allowed to remain engaged and focused on the AM problem, and they must have long-term resources available that are adequate for answering key questions. The MAST (2015) conceptual model is not only an exceptional document; it is a convincing demonstration of the high level of coordination, cooperation, and thoroughness that the MAST team is capable of achieving. In the Panel's opinion, a project as important as WaterFix deserves the best ecological support possible and California is fortunate to have the MAST group available to provide this service.

Second, the use of any historical data needs to be explicitly qualified regarding its potential limitations. A number of investigations have analyzed the entire periods of record for monitoring time series (e.g., Miller et al. 2012). It is very ambitious to explain trends that are responses to decades of development in the Delta, its watershed, and San Francisco Bay. While de-convolving all of the various continuous, stepped, punctuated, stochastic, and cumulative influences on the Delta's ecosystem would be ideal (e.g., Nobriga and Rosenfield 2016), there has been a clear limit on model precision at this lengthy historical scale, and this is what led Reed et al. (2014) to state "the rate of learning about the efficacy of alternate flow policies in the Delta will likely be very slow," and more specifically, that existing monitoring programs and associated models are not sufficient for use in passive, flow-based AM implementation for Delta Smelt. New types of information are needed, and efforts to collect this new information need to be carefully designed in order for the AM process to be efficient and effective. This process has already started, and the rate of learning has been increasing dramatically in recent years. A well-directed, methodical momentum needs to be maintained into the future. An example of a promising approach was taken by MAST (2015), who demonstrated a hypothesis-based investigation of 2011, which was an isolated, successful year for Delta Smelt. Notably, they intentionally restricted their investigation to passive variations among four recent years, which eliminated the confounding effects of the long-term changes to the Delta ecosystem. This approach, along with active AM experiments when feasible, is likely to continue to be productive. The MAST group envisions eventual combination of conceptual models with mathematical models to provide a substantial improvement on the guidance for AM of projects such as WaterFix.

Third, a very large number of future studies have been proposed at various times, but these need to be placed into an organized, hypothesis-driven structure (i.e., as provided by the Delta Smelt conceptual model) in order for these studies to be most effective. Lists of proposed studies occur in BDCP documents, in the MAST (2015, Table 10) conceptual model, and in the BA (Table 6.A-11, which was taken from the Collaborative Adaptive Management Team Fall Outflow Workplan). Combinations of studies will likely work best to fill information gaps in the Delta Smelt conceptual model. During the April 2016, Panel meeting in Sacramento, many specific studies were mentioned by presenters, guests, or the Panel members themselves. Some of these are redundant to the above lists, but are repeated here as a matter of record, with no particular emphasis or priority implied by the Panel:

- Underwater cameras for nonlethal monitoring (SmeltCam, Feyrer et al. 2013)
- DIDSON (acoustic video) for nonlethal monitoring in turbid waters
- Ecogeochemical forensics (stable isotopes, otolith microchemistry; making the most of incidentally collected Delta Smelt specimens)

- Turbidity studies
- BACI-design predator-prey studies at the NDD
- Environmental DNA (eDNA) for qualitative tracking of Delta Smelt habitat use, especially to help pinpoint spawning locations
- More diet studies of Delta Smelt and Delta Smelt predators
- Characterizing otolith-based growth rate/ microchemistry/stable-isotope differences between survivors (older individuals) and the original population (younger individuals) of the same cohort
- Direct measurement of vital rates as habitat quality metrics
- Studies of variation in size-specific fecundity (similar to what is also mentioned by MAST 2015)

In addition, the MAST (2015) suggests that concurrent zooplankton sampling should be "a routine part of the four major surveys monitoring Delta Smelt." Although some zooplankton sampling has been ongoing since 2005, the MAST (2015) authors noted a number of aspects that could be improved. Finally, Grossman et al. (2013) suggested a "more comprehensive food web modeling approach could be used to assess the role of predation on populations."

2.4 Effects on Longfin Smelt

Diverse opinions and considerable speculation characterize our understanding sources of mortality to Longfin Smelt. One direct source, entrainment in the southern Delta export facilities, and multiple indirect effects related to Delta outflow, food availability and spawning habitat, have been postulated as mortality factors and inhibitions to Longfin Smelt conservation and recovery. Perhaps a root cause of uncertainty is that a population-level context for Longfin Smelt abundance appears to be unreliable and take estimates seem best expressed as a proportion of an uncertain population. This is a precarious foundation for assessment of NDD impacts in preparing the BO.

The draft Analytical Approach for Longfin Smelt (AALS) suggests that entrainment at the export facilities has been relatively low during most water year types. However, this suggestion is uncertain because Longfin Smelt entrainment occurs during the same period as Delta Smelt and salmon, and because fish <20 mm in length are not enumerated. Alternatively, some studies have argued that entrainment (or proxies thereof) is not a driver of population dynamics (MacNally et al*.* 2010, Thomson et al*.* 2010, Maunder et al*.* 2015).

Both the draft AALS and the proposed approach for Section 7 permit application utilize the Particle Tracking Model (PTM) capability to predict potential entrainment. This corresponds to Grimaldo et al*.* (2009) findings that adult Longfin Smelt salvage at the southern Delta export facilities was significantly negatively related to mean Old and Middle River flows in December–February. However, a number of concerns have been expressed about the DSM2-PTM methodology based on the frequency, location, and unresolved fate of particles from the 45 day PTM analysis (CDFW 11/3/2015 draft take analysis) as well as other model issues (See Section 2.4.1).

Other potential limiting factors on Longfin Smelt abundance relate to winter-spring outflow from the Delta where the Fall Midwater Trawl abundance index suggests that increased Delta outflow promotes conditions that increase survival of larvae and small juveniles during winter and spring, producing increased abundance during fall of the first year of life (Rosenfield and Baxter 2007). Several mechanisms are postulated including greater residence time in suitable feeding and rearing habitats with greater stratification (Kimmerer 2002, Kimmerer et al*.* 2009) and the increased availability of suitable spawning habitat (Grimaldo et al*.* 2014) in western reaches of the Delta such as adjoining Suisun Marsh. None of these hypotheses have been validated and some are confounded by other systematic changes such as the effects of non-indigenous clams on primary and secondary production. Alternative analyses have also suggested that Delta outflow effects may subsequently be tempered by density-dependent survival in the juvenile life stage in marine or mesohaline waters outside the Delta, which implies that small effects of slightly lower Delta outflow under the PA may not accumulate over time (Norbriga and Rosenfield 2016).

While there are intrepid efforts through monitoring, analyses and research to resolve the unknown aspects of the Longfin Smelt population and its limiting factors, the uncertainties remain daunting. This level of multifaceted uncertainty suggests to the Panel that the BA's conclusions of "very little difference in terms of predicted Longfin Smelt relative abundance between NAA and PA" in the Delta outflow relationship, or that "larval Longfin Smelt entrainment under PA would be less than under NAA" must remain speculative until smelt population dynamics is better understood. Given the persistent uncertainties about the risk and vulnerability of Longfin Smelt to the PA, the Panel reinforces the BA's emphasis on real-time management and monitoring to minimize entrainment effects under the PA. In the interim, efforts to improve acknowledged inadequacies in monitoring design and research to fill the major gaps in Longfin Smelt life history need to be concerted.

2.4.1 Particle Tracking Model (PTM) issues for Longfin Smelt

The AALS had some very specific questions related to the DSM2 particle tracking modeling. A summary of those issues is as follows (Draft AALS, pg. 4):

> In comments provided on the 11/3/2015 draft take analysis, DFW had concerns regarding the frequency, location, and unresolved fate of particles from the 45 day PTM analysis. Regional density differences were taken into account, but not temporal (across survey) differences. Taking means of means reduces variability across water year types. Ideally CDFW desires bi-weekly injections, injection locations, number of particles injected, a greater temporal period for particle transport (i.e., 90 days), and additional flux locations to better illustrate the fate of unresolved particles (i.e., particles that do not reach Chipps Island or the CVP/SWP southern Delta export facilities) (CDFW notes that there is evidence (spring of 2012) that reduced southern Delta export pumping and low outflows in the hatching/larval period are capable of translating to increased juvenile salvage. Essentially, larvae may have been unable to exit the central and southern Delta because of low flows, and subsequently grew large enough to be counted in salvage (only fish 20 mm and larger are measured)). For this reason, CDFW suggests further exploration of the fate of unresolved particles from the PTM.

Before any more PTM modeling is done for this application, the results of this analysis need to be reviewed by hydrodynamic modelers to determine whether the particles are being stranded in the simulations due to model representations. Because the DSM2 model is a one-dimensional model, the open water regions of Franks Tract and Mildred Island are each represented as a continuously stirred tank reactor (CSTR). The DSM2 model has been calibrated such that the input/output from the CSTR can represent salinity intrusion into the Delta system. The use of the CSTR was not intended to represent the actual circulation patterns in these open water regions. Therefore, if particles are getting “stuck” in the CSTRs, this is likely a limitation of the model representation of circulation in these regions. All the CDFW suggestions on page 4 (draft AALS) to improve the PTM results assume that the underlying transport physics are well represented. Unfortunately, this is likely not the case.

2.5 Estimating and Interpreting Quantitative Uncertainties

2.5.1 Quantitative Uncertainties in the BA

The BA compares the projected effects, on fish, of future scenarios for the NAA and the PA. The Panel believes that the BA strategy for making these comparisons does not adequately represent their quantitative uncertainties. We describe three main concerns by using the model predictions for the Longfin Smelt abundance index (BA, Appendix 4.A, Section 4.A.1) as an example. However, our concerns also apply to similar statistical models used throughout Ch. 4-6 of the BA.

All BA projections are subject to two general sources of uncertainty. The first source is that values of the Delta's environmental variables (flow, X2, temperature, etc.) are unknown for future years. The BA defines 82-year scenarios for NAA and PA that specify probable future values of these environmental variables. These future values are then used as inputs to fish response models. The resulting response-model predictions are then summarized over the 82-period, using boxplots of yearly point predictions grouped by water-year type (for example, Figure 4.A-1). The BA also presents exceedance plots showing the NAA versus PA distributions of point predictions over the full 82-year period (for example, Figure 4.A-2). The Panel believes that these plot formats do a good job of displaying the first source of uncertainty.

However, these boxplot and exceedance plot formats do not represent the second general source of uncertainty, namely, the uncertainty of any prediction made by a fish response model for a given set of environmental predictor values. The Panel’s first concern is that the boxplot and exceedance plot formats may be misinterpreted as representing the overall uncertainty of future fish responses to NAA and PA, which more realistically should include both the environmental and the model-prediction uncertainties. Below, we suggest how these plot formats might be restructured to include both sources of uncertainty. ***If both sources cannot be included, then we recommend that the boxplot and exceedance plot figure legends state that the plots exclude model uncertainty.***

2.5.1.1. Constructing confidence intervals

The BA does address the model prediction uncertainty of each fish response model, in all cases where those uncertainties can be estimated. The Panel approves of these efforts. For Figures 4.A-1 and 4.A-2, the fish response model is a simple linear regression, whose model-prediction uncertainty can be quantified using a confidence interval (CI) around each point prediction. The width of that CI is a function of the standard errors of the estimated regression coefficients, plus the square root of the model's mean-squared error (MSE), which measures the scatter of the model-fitting data around the estimated regression line (Neter et al. 1983). In Figure 4.A-7, such CIs are plotted as envelopes surrounding the projected 82-year time series of NAA and PA fish responses. This figure format has the advantage of displaying both the environmental and model-prediction sources of uncertainty.

However, the Panel's second concern is that the CIs in Figure 4.A-7 are too narrow, because they do not accurately represent the full uncertainty of regression model predictions. Our greatest concern here, and with other similar examples, is that the CIs describe only the uncertainty of the mean model response, that is, of the location of the regression line. Instead, the CIs should also include the MSE to represent the uncertainty of an individual prediction; they should be "prediction intervals" (Neter et al. 1983). Unfortunately, the regression model for Figures 4.A-1, 4.A-2 and 4.A-7 was obtained from a source (Kimmerer 2009) that did not report the MSE, which is needed to construct prediction intervals.

The Panel recommends that the BO authors obtain the full set of regression statistics for all regressions used in PA and NAA projections, so that true prediction intervals can be constructed for all figures like Figure 4.A-7 of the BA. Failing that, the legends on such figures should probably state that the plotted CI's are too narrow by an unknown amount, because they are not true prediction intervals.

Returning to the Panel's first concern, it should be possible to modify the boxplot format of Figure 4.A-1 to include both environmental uncertainty and model prediction uncertainty. One could replace each box with the mean, across all years in a year type, of the point predictions, and then bracket those means by approximate CIs that are based on both sources of uncertainty. We sketch three ideas for constructing such CIs:

1) Make the predictions using Monte Carlo simulation, with a random residual error (mean=0, variance = MSE) added to the regression model's prediction on each trial in each year.

2) From Figure 4.A-7, extract the largest upper confidence bound and the smallest lower confidence bound, among all years in a year type. Use these as the upper and lower bounds of the CI on all predictions for that year type. This might require a Bonferroni adjustment to control the family-wise confidence level for the multiple prediction intervals, across a year type, that this approach would encompass (Neter et al. 1983).

3) Insert estimates into the law of total variance ("Eve's law"): Var(Y) = E[Var(Y|X)]+Var(E[Y|X]). In this expression, Var(Y) is the estimation variance of the response predictions (Y) in a year type, which will include both uncertainty sources, and X is one year in a year type. The first term on the right-hand side can be simply approximated by the MSE, which is the same for all predictions. A more complicated and accurate alternative would be to calculate the mean, overall years in the year type, of the full model prediction variance for each year. This first term then quantifies model prediction uncertainty. The second term on the right-hand side is the variance of the point predictions, over the years in the year type. This second term quantifies environmental uncertainty. Once Var(Y) has been estimated, construct a symmetric 95% CI around the mean of the point predictions for the year type, using a half-width of 1.96*sqrt(Var(Y)).

2.5.1.2 Interpreting model predictions and confidence intervals

During the Panel's public meeting with agency representatives, a representative asked what purpose would be served by showing wider, albeit more realistic, CIs in Figure 4.A-7, and in similar figures elsewhere. Although he did not elaborate, his reasoning may have been as follows: The CIs for PA and NAA already show nearly 100% overlap in Figure 4.A-7 and similar figures elsewhere, and the same very high overlap would also be seen with wider, more-realistic CIs. Thus, it would seem that, even though they might become wider, the more-realistic CIs would still imply that the "true", real-world effects of PA and NAA on fish are predicted to be very similar.

However, the Panel's third concern is that the CIs in time series plots such as Figure 4.A-7 are not being interpreted rigorously. This misinterpretation becomes more serious for realistically wider CIs. To rigorously interpret the CIs, we recommend redrawing Figures 4.A-7 to 4.A-9, while omitting the solid lines showing the point (mean) predictions for PA and NAA. Those solid lines have little relevance, because all that we know, with 95% confidence, is that the "true" (real-world) PA value for any year will lie *somewhere* within the PA confidence bounds, and that the true NAA value for that year will lie *somewhere* within the NAA bounds. Thus, it is possible that true yearly values for PA lie near the bottom boundary of the CI for PA, while true NAA values lie near the top boundary of the CI for NAA. If more-realistic CIs are even wider than those in Fig. 4.A-7, then such large differences between the true PA and NAA values may be biologically significant, even though such differences lie entirely within the overlapping CIs for PA and NAA. In other words, if a fish response model makes very similar point predictions for PA and NAA, but that model has high prediction uncertainty, then we have little confidence that the real-world outcomes for PA and NAA will also be similar.

The Panel recommends that time series plots such as Figure 4.A-7 omit the solid lines depicting the point predictions from the fish response model, because the point predictions are unlikely to be the actual future outcomes.

Finally, we note a more subtle consequence of using weak regression models, such as the regression model with $r^2 = 0.36$ that was used to predict Longfin Smelt entrainment (Sec. 2.3.2). If a regression model has high uncertainty (low r^2), then its coefficients tend to be small in magnitude; in the extreme case of their statistical non-significance, the coefficients cannot be distinguished from having zero magnitude. And small regression coefficients imply that model predictions are not very sensitive to changes in the predictor variables. Thus, weak regression models will generally predict similar fish responses to the PA and NAA scenarios, even if those scenarios assume distinctly different values for flow, X2, temperature, and other environmental driving variables. In other words, the small differences between the point predictions for PA and NAA, which are evident in many plots like Figures 4.A-1, 4.A-2 and 4.A-7, may be largely due to the use of highly uncertain fish response models.

2.5.2 Confronting Uncertainty in the Analytical Approach for the BO (AABO)

The Panel's understanding is that the final BO will draw heavily on the methods and results of the BA. Thus, if the BA frequently underrepresents the uncertainties of its model projections, the Panel is concerned that the BO developers may view uncertainty as a somewhat minor issue, and may also accept the BA models' point predictions as highly likely outcomes. The Panel sees evidence of this in the draft AABO, which mentions "uncertainty" only three times, two of which relate only to uncertain future climate. In particular, the conceptual model for determining a jeopardy opinion (Figure 1, AABO) makes no mention of uncertainty. We note that treating uncertainty as a minor issue is inconsistent with McElhany et al. (2000), whose guidelines for Viable Population Size, Critical Population Size and other VSP components all contain at least one guideline that specifically targets uncertainty.

The draft AABO may be trying to address uncertainty, albeit indirectly, with its intention to assess the "weight of evidence" for the effects of each action component (Table 2-1, AABO). However, although "weight of evidence" is an attractive concept, it is difficult to quantify in any objective way. ***The Panel recommends that the AABO describe how weights of evidence will be determined.***

The Panel also believes that the AABO needs to address uncertainty more directly when formulating its decision-making sequence for determination of jeopardy (AABO Table 2-2). At present, the decision sequence assumes that accurate True/False decisions can be made about the "likelihoods" of stressor occurrences, species exposures, species responses, and so forth. For the True/False decisions to be objective, such likelihoods should be quantified whenever possible. However, likelihood estimates will be highly uncertain in many cases. For example, due to model-prediction uncertainty, suppose that a likelihood (probability) is estimated to be 0.6 (likely), but the CI on that estimate ranges from 0.35 (unlikely) to 0.85 (likely). How would such a result be translated into a True/False decision about the likelihood? ***The Panel recommends that the AABO specify how decisions will be made when likelihood estimates, and projected changes in likelihood, are highly uncertain.***

2.6. Adaptive Management (AM)

According to Section 7 of the ESA, the USFWS and NMFS (the Agencies) must include in the BO a determination of whether or not the PA will lead to Jeopardy or Adverse Modification of Critical Habitat. The Panel suggests that such a determination must be based on (1) an accurate acknowledgement of the high degree of uncertainty regarding the effects of the PA; and (2) because of the legal obligation to err on the side of the species in cases where there is high uncertainty and insufficient data, a critical examination of the extent to which the PA includes adequate provisions for responding to new information about its effects on the species and critical habitat in ways that will prevent jeopardy to the species and/or adverse modification of habitat.

Put differently, there are potentially three ways the Agencies can deal with the lack of certainty and data inherent in assessing the effects of the PA. The first two are clearly stated in the Section 7 Consultation Handbook. Where significant data gaps exist there are two options: (1) if the action agency concurs, extend the due date of the BO until sufficient information is developed for a more complete analysis; or (2) develop the BO with the available information giving the benefit of the doubt to the species, which could result in a jeopardy opinion preventing the PA from going forward. A third possible way to err on the side of the species in situations where uncertainty is high would be to go forward with the project (no jeopardy with Reasonable and Prudent Measures (RPMs), or Jeopardy with Reasonable and Prudent Alternatives (RPAs)) with a firm commitment and explicit plans to modify management as needed to avoid Jeopardy or Adverse Modification as new information becomes available, e.g. through adaptive management (AM) and, where AM is not practical or feasible, structured decision making and/or scenario planning (see Allen et al. 2011 and the special issue of *Journal of Environmental Management* in which it appears for a comprehensive overview of these different approaches to natural resource management decision making).

AM is an approach to natural resource management aimed at reducing uncertainty, building knowledge and improving management outcomes over time. It goes beyond a trial and error approach in that it involves careful articulation of goals, identification of alternative management objectives, hypotheses of causation and developing procedures for the collection of data followed by evaluation and reiteration (Allen et al. 2011).

AM is a form of structured decision making (SDM), which is an organized and transparent approach to making decisions by identifying and evaluating alternatives and justifying complex decisions (Allen et al. 2011). AM is more robust than SDM, however, because, when done correctly, it adds to the process iteration and theoretically results in higher order learning.

A distinction is often made between “active” and “passive” AM based on the way uncertainty is recognized and treated. In active AM, managers attempt to reduce uncertainty by deliberately probing for information to evaluate testable hypotheses about the effects of interventions, while in passive AM, there is a lack of explicit experimentation and learning is a “useful but unintended byproduct of decision making” (Williams 2011). While both are useful for achieving management objectives in different contexts, they differ in the degree to which the objectives that guide decision making emphasize the reduction of uncertainty.

AM scholars generally agree that active AM is preferable, but realistically only feasible where both uncertainty and controllability are high, i.e., where the system can be manipulated to allow for structured experimentation. When uncertainty is high and controllability is low, developing and analyzing scenarios through “scenario planning” is generally considered more appropriate (Allen and Gunderson 2011, Peterson et al. 2013).

Scenario planning refers to a framework for developing more resilient conservation policies when faced with high uncertainty and high uncontrollability. Peterson et al. (2013) characterize a scenario in this context as “an account of a plausible future”:

> “Scenario planning consists of using a few contrasting scenarios to explore the uncertainty surrounding the future consequences of a decision. Ideally, scenarios should be constructed by a diverse group of people for a single, stated purpose. Scenario planning can incorporate a variety of quantitative and qualitative information in the decision-making process. Often, consideration of this diverse information in a systemic way leads to better decisions. Furthermore, the participation of a diverse group of people in a systemic process of collecting, discussing, and analyzing scenarios builds shared understanding “(Peterson et al. 2013).

The Panel recommends that the BO includes a critical analysis and evaluation of the approach to AM proposed in the PA for two main reasons. First, best available science suggests that, where feasible, AM is the best way to deal with uncertainty and assess and respond to the effects of management actions so as to be able to address unexpected outcomes and the need for mid-course corrections, and to continue to learn and fill data gaps. This is the approach recommended in McElhany et al. (2000), and in numerous past reviews of the CVP/SWP, and precursors of the current PA.

Second, it is in the Agencies' best interest to work out the details of the AM program in the BO to avoid possible legal challenges. An adaptive management approach is legally mandated by the Delta Plan and it is generally expected by courts reviewing ESA decisions. Fischman and Ruhl (2015) investigated U.S. Federal Courts opinions published through January 1, 2015 to understand how AM has been judged in the courts and they identified three shortcomings in AM implementation that recur in judicial cases overturning agency decisions: (1) failure to establish objectives or failure to describe monitoring protocols for a plan or project; (2) failure to define decision thresholds in monitoring; and (3) failure to identify specific actions that will be triggered when thresholds are crossed.

These ideas have already been explored by courts in the context of the Bay Delta system. In a series of decisions regarding ESA compliance in the operation of the CVP between 2006 and 2011, Judge Wanger looked at how agencies may rely on AM to ensure that water operations will not "jeopardize the continued existence" of any listed species. He compared the conservation approaches of the FWS in regard to the Delta Smelt with NMFS approach in regard to the anadromous fishes. While both agencies employed AM, Judge Wanger upheld the NMFS approach and remanded the FWS plan. While the NMFS AM protocol contained definite, substantive criteria (e.g., temperature thresholds) that triggered revision of the water system operations to avoid jeopardy, the FWS approach failed to provide enforceable, precise criteria to serve as thresholds. The Judge also overturned the FWS adoption of "a procedurally elaborate" AM protocol identifying danger thresholds for the Delta Smelt because it failed to specify what alternative actions would be taken if the threshold was crossed, saying only that it would convene a working group to "consider" a range of operational changes in the water system. In contrast, the NMFS approach specified specific enforceable requirements that would be imposed if the system crossed thresholds for the anadromous fish (Fischman and Ruhl 2015).

Therefore, to ensure that the BO is in alignment with the best available science and is legally defensible, a management program that includes active AM, where feasible, along with passive AM, should be an integral part of the PA and should include explicit plans for ongoing monitoring of the status of the species and the direct and indirect effects of (1) the design of fish facilities (the footprint of the PA installation), (2) the operations (whether the PA is jeopardizing species or adversely modifying habitat), and (3) restoration and mitigation activities (to determine how they are affecting the species and whether the PA is working to move toward recovery).

Based on the BA, it is clear that the action agency and applicant intend to employ an AM approach to the design and operation of the proposed facilities to prevent jeopardy and adverse modification throughout the life of the project and to the restoration/mitigation aspects of the PA to ensure that recovery is progressing. Chapter 3 of the BA has numerous references to AM and in each case the reader is referred to Section 3.4.7, Collaborative Science and Adaptive Management Program, for details. However, Section 3.4.7 simply states that the AM program "will be used to consider and address scientific uncertainty regarding the Delta ecosystem and to inform implementation of the operational criteria in the near term for existing BiOps … as well as in the future for the new BiOp and 2081(b) for this PA." (BA 3-72). What is unclear is exactly how AM will be structured, how it will be funded, and how it will be carried out. Directing explicit attention to the adequacy of AM plans in the forthcoming BO will be important because the Panel is in agreement that the treatment of AM in the BA is lacking in important details.

Since there is currently no mention of AM or even monitoring in the AABO, the inadequacy of the PA's plans for AM is likely to be overlooked unless the AABO is revised***. Therefore the Panel recommends that the Agencies articulate an explicit plan in the AABO for evaluating the adequacy of the plans for AM, based on best available knowledge regarding effective AM design and implementation.***

The next subsections describe features of a strengthened AM plan.

2.6.1. AM structure

The BA says AM for the PA "will build on CSAMP and CAMT". More details are needed in writing the BO. Will there be a new Delta AM team? What will be the criteria for selection to the team? Will there be independent review of the AM program? And how will the AM program be funded?

2.6.2 AM Process

The BO should provide more details about how AM will be carried out to reduce the chances of jeopardy or adverse modification related to (1) the design of facilities, (2) operations, and (3) restoration/mitigation. AM should also be used to flesh out conceptual models of species' life cycles that currently are incomplete or are missing information. The approach to assessing future effects should include explicit commitment to taking advantage of surprise events to learn (floods, droughts, levee failure events, alternative operations such as the False River emergency barrier installation in 2015). In addition, baseline monitoring of water quality, water circulation (flow, velocity), fish population attributes (both of listed species and predator communities) at the NDD inlet locations should begin in 2016 so that the effects of the PA and the effectiveness of adaptive management approaches can be measured when the PA comes online.

In the context of the PA, an active AM approach would seek to learn more about and be responsive to both direct and indirect effects of the PA and would include:

- Clear objectives for each species
- Description of monitoring protocols
- Indicators and triggers for various anticipated impacts
- Establishment of decision thresholds based on monitoring data
- Specification of actions that will be triggered when thresholds are crossed.

The BA continually refers to Section 3.4.7 (Collaborative Science and Adaptive Management Program), and AM generally, but is lacking in details about monitoring plans and triggers. For example, Sections 3.1.5 and 3.3.3 of the BA describe the real-time decision process, aimed at responding to the potential for adverse conditions as they arise, but there is no information to judge how effective this process would be under the PA. The BA does not attempt to consider the effects of real time management, instead deferring such assessment to the future, saying that *"the operating criteria will be periodically evaluated and possibly modified through the adaptive management process"* (BA 3-97). We recommend that the real-time operational decision making process be linked more explicitly to a formal AM program.

As stated earlier in this report, the BO should describe the management guidelines and actions for reservoirs on the Sacramento and American Rivers that are linked to conditions in the Delta such that flows released from the reservoirs would be altered in response to the PA. If these actions involve real-time management of the reservoirs, what are the conditions in the Delta that would cause change in water released from the reservoirs?

In addition, baseline monitoring of water quality, water circulation (flow, velocity), fish population attributes (both of listed species and predator communities) at the NDD inlet locations should begin in 2016 so that the effects of the PA and the effectiveness of adaptive management approaches can be measured when the PA comes online.

2.6.3 Adaptive Management Challenges

*C*ompliance with the ESA through AM is difficult. The ESA assumes a "linear process of examination...a single, well-defined 'agency action,'" which is counter to the assumption of complexity, non-linearity, and uncertainty of AM. Laws and regulations associated with the ESA focus on preservation and minimization of human impact and persistence of certain individual species. They enforce a front-end approach where the underlying assumption is that people can predict outcomes of a certain action before that action has taken place. Trying to reconcile the two paradigms is difficult.

The Panel acknowledges the challenges associated with implementing active AM in the Bay Delta context. Numerous independent scientific review panels and other reports have commented on this over the years. The Panel also recognizes that the BO will not be able to pre-plan AM triggers for every decision; and that some potentially harmful effects will be easier to respond to than others. For example, unanticipated impacts related to flows may be more difficult to plan for and respond to than non-flow related impacts.

Finally, in the draft BO the Agencies should consider which aspects of the PA demand active AM to reduce the risk of jeopardy or adverse modification, and which aspects should be managed with other structured decision making approaches (Allen et al. 2011). As stated above, according to the best available science related to decision-making in complex adaptive systems, in cases where there is high uncertainty, low controllability, and high risk (e.g., where the remaining listed species are few in number), an experimental approach may not be feasible or appropriate (Allen and Gunderson 2011). In those cases, structured decision making involving scenario planning may be more appropriate than AM. The Agencies should commit to a process of determining when and in relation to which aspects of the PA AM is appropriate, and where it is not feasible or where the stakes are simply too high for an experimental approach. These determinations and their rationales should be clearly stated in the BO.

3. List of Panel Recommendations

The following table lists the Panel's recommendations, indicating their location (section and page number) in this report. Recommendations are numbered by their order of occurrence in the report, and the numbers do not represent their importance or priority for action. In the table, the Analytical Approach to the BO is designated "AABO".

Number	Recommendation	Section	Page
1	That the evaluation of the influence of climate change on the PA operations should be longer than 2030.	2.1.4	21
2	Evaluate the compounding effect of the PA and dry years, and the potential for depensatory mortality, using a series of continuous dry years.	2.2.3	25
3	That all fish screen criteria described by NMFS (2011) should be explicitly addressed in the BO.	2.2.4.1	27
4	Additional effort to evaluate PA effects on critical salmonid habitats, including natural and restoring tidal wetlands predictably under the large-scale influence of the NDD operations.	2.2.5	29
5	Evaluate water removal effects (up to ~40% of Sacramento River flow depending on month and water year) during tail end migration periods when juvenile salmonid abundance is low, in addition to when most juveniles are present in the Delta.	2.2.6	30
6	Evaluate the extent to which the PA may alter the abundance of Striped Bass and other predators that consume ESA-listed species.	2.2.7	30
7	Evaluate the PA effects on wild fry, parr and smolt migrants, given that Fall-run Chinook Salmon are likely an important prey of Killer Whales.	2.2.7	31
8	That the AABO describe how it will evaluate project effects on diversity and spatial structure.	2.2.8	32
9	That approaches for using precaution and adaptive management be described in the AABO.	2.2.8	32
10	That the abiotic habitat effects of the PA be explicitly considered within the context of the new Bever et al. (2016) findings, while recognizing that this exercise cannot include turbidity due to lack of a turbidity model for the PA simulation	2.3.4	43

	(i.e., the abiotic station index of Bever et al. 2016 should be modified to include salinity and current speed, but not turbidity). We also recommend that the water-distribution system within Suisun Marsh be qualitatively assessed for its potential influence on the salinity, current speed, and turbidity within the high-abundance area for Delta Smelt, as described above and as identified in Figure 2.		
11	That boxplot and exceedance plot figure legends state that the plots exclude model uncertainty, unless that uncertainty can be incorporated.	2.5.1	49
12	That the BO authors obtain the full set of regression statistics for all regressions used in PA and NAA projections, so that true prediction intervals can be constructed for all figures like Figure 4.A-7 of the BA. Failing that, the legends on such figures should probably state that the plotted CI's are too narrow by an unknown amount, because they are not true prediction intervals.	2.5.1.1	50
13	That time series plots such as Figure 4.A-7 omit the solid lines depicting the point predictions from the fish response model, because the point predictions are unlikely to be the actual future outcomes.	2.5.1.2	52
14	That the AABO describe how weights of evidence will be determined.	2.5.2	53
15	That the AABO specify how decisions will be made when likelihood estimates, and projected changes in likelihood, are highly uncertain.	2.5.2	53
16	That the BO includes a critical analysis and evaluation of the approach to adaptive management (AM) proposed in the PA.	2.6	55
17	That the Agencies articulate an explicit plan in the AABO for evaluating the adequacy of the plans for AM, based on best available knowledge regarding effective AM design and implementation.	2.6	57

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Appendix 1 – Materials for CA WaterFix Aquatic Science Peer Review – Phase I

For Review:

1. NMFS Biological Opinion Draft Analytical Approach
    a. Draft analytical approach
    b. South Delta Conceptual Model

2. 2016 CWF Biological Assessment (BA) Sections for Review
    a. Chapter 6 (Delta Smelt Effects Analyses only)
    - Chapter 6: Effects Analysis for Delta Smelt
    - Appendix 5.A, CalSim II Modeling and Results
    - Appendix 5.B, DSM2 Modeling and Results
    - Appendix 5.G, Projects to Be Included in Cumulative Effects Analysis for the Conveyance Section 7 Biological Assessment
    - Appendix 6.A. Quantitative Methods for Biological Assessment of Delta Smelt

    b. Chapter 5 (Salmonids and Sturgeon Effects Analysis)

    Note: All methods sections listed can be found in Appendix 5.D Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley steelhead, Green Sturgeon, and Killer Whale

    - Section 5.4.1.3.1.1.1 North Delta Exports: For overall species response to this component of the proposed action Methods: Section 5.D.1.1.1 North Delta Exports (for near-field effects only; other effects are in Sections 5.D.1.2 Indirect Mortality Within the Delta (Through-Delta Survival) and 5.D.1.3 Habitat Suitability)

    - Section 5.4.1.3.1.1.1 North Delta Exports and 5.4.1.3.1.1.1.3 Predation: For effects of intakes on predation and travel time

Methods: 5.4.1.3.1.1.1.2 Impingement, Screen Contact, and Screen Passage Time (assuming "travel time" = screen passage time)

There is no analysis of predation in Appendix 5.D

- Section 5.4.1.3.1.2.1 Indirect Mortality Within the Delta: For characterization of effects that are in-Delta yet beyond the immediate vicinity of the north Delta intakes

Methods: Section 5.D.1.2 Indirect Mortality within the Delta (Through-Delta Survival)

- Section 5.4.1.3.1.2.1.3. Through-Delta Survival: For consideration of effects on population of performance criteria of minimum 95% survival rate through north Delta intake reach

Methods: Section 5.D.1.2.2 Delta Passage Model, Section 5.D.1.2.3 Analysis Based on Newman (2003), Section 5.D.1.2.4 Analysis Based on Perry (2010), and Section 5.D.3 Life Cycle Models

- Section 5.4.1.3.1.2.2.1.1 Bench Inundation: For effects of habitat loss in north Delta due to operations of north Delta intakes

Methods: Section 5.D.1.3.1 Bench Inundation

- Section 5.4.2.1.3.1.1 Spawning, Egg Incubation, and Alevins: For effects of operations in upstream areas during summer and fall months, especially given inability of modeling to capture real-time management

Methods: Section 5.D.2.1 Water Temperature Methods and Section 5.D.2.2 Spawning Flow Methods

3. Longfin Smelt Analytical Framework and Effects Analysis

   a. Draft Analytical Approach
   b. 2081 Take Analysis
   c. Longfin Smelt Quantitative Analyses

d. PTM results

Background information:

Biological Assessment

1. 2016 CWF Biological Assessment

   a. **DSM2 Grid Version 2.0**

Federal Policies and Guidance

2. USFWS Section 7 Analytical Framework, p.138-139
3. Endangered Species Act Section 7 Consultation Handbook
4. 2008 USFWS Biological Opinion on the Long-Term Operational Criteria and Plan (OCAP) for coordination of the Central Valley Project and State Water Project
5. Designated Delta Smelt Critical Habitat Map
6. Designated Delta Smelt Critical Habitat
7. NMFS Aquatic Species Critical Habitat
8. Warranted But Precluded 12-Month Finding to Uplist Delta Smelt to Endangered Status

Research

9. Lindley et al. 2007
10. McElhaney et al. 2000
11. **2015 Final MAST report** "An updated conceptual model for Delta Smelt: our evolving understanding of an estuarine fish."
12. Final Report on Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem
13. Effects Analysis State Water Project Effects on Longfin Smelt, California Department of Fish and Game, 2009.
14. Nobriga, M. L., and J. A. Rosenfield. 2016. Population dynamics of Longfin Smelt in the San Francisco Estuary II: disaggregating forces driving long-term decline of an estuarine forage fish. Transactions American Fisheries Society 145(1):44-58

15. **FINAL REPORT:** A Synthesis of Delta Smelt Growth and Life-History Studies, Prepared for the California Department of Fish and Wildlife by: James A. Hobbs, Department of Wildlife, Fish and Conservation Biology University of California-Davis, December 2015.

Reviews

16. Independent Review Panel Report: BDCP Effects Analysis Review, Phase 3 - March, 2014
17. Report of the 2015 Independent Review Panel on the Long-term Operations Biological Opinions (LOBO) Annual Review (December 16, 2015)
18. Delta Smelt 5-Year Review

Supplemental Materials Requested by the Panel:

- **DWR Delta Simulation Model Grid Version 2.0**
- **2016 CWF Biological Assessment Appendix 5.B Figure 5.B 2-3**
- **2016 CWF Biological Assessment Appendix 5.B Figure 5.B.2-6**
- **Sobeck 2016**
- **20mm Longfin Smelt monitoring methods**
- **Fish Facilities Study Work Plan**
- **2016 CWF Biological Assessment Section 3.4.8**

Additional Materials Provided at the Review:

- **Mount et al., 2013**
- **Vogel et al., 2008**

Presentations:

- **Project Overview –BG Heiland (DWR)**
- **Endangered Species Act Overview: Section 7 Process and Biological Opinion –Jane Affonso (USFWS), Erin Strange (NOAA)**

- A Brief Overview of the California Endangered Species Act and Incidental Take Permitting –Shannon Little (CDFW)
- Status Update ESA Section 7 Consultation for California WaterFix –Kim Turner (USFWS)
- NMFS Biological Opinion Draft Analytical Approach for Salmonids and Sturgeon -- Cathy Marcinkevage (NOAA)
- Salmonids and Sturgeon Effects Analysis –Rick Wilder/Marin Greenwood (ICF)
- Delta Smelt Effects Analyses –Marin Greenwood (ICF)
- Longfin Smelt Analytical Framework and Effects Analysis –Marin Greenwood (ICF)
- Independent Science Panel Initial Recommendations

Public Comment:

- 2016 California WaterFIx Aquatic Science Peer Reivew –Doug Obegi, Natural Resources Defense Council
- Major Modeling Issues for the WaterFix Biological Assessment –Deirdre Des Jardins, California Water Research
- 2016 California WaterFix Aquatic Science Peer Review –State Water Contractors

Appendix 2. Memo from M. Greenwood on modeled Sacramento R. flows. See attached document, ICF_Hydrograph.pdf.

Panel note on Appendix 2:

In Appendix 2, there is subtle change noted in the figure notes that state the Sacramento Inflow is defined at a location south of the NDD withdrawal facilities rather than at its traditional location at Freeport. This change gives the impression that the NDD withdrawal is at a location above the Delta. However, the inlet locations are south of Freeport, in the legal domain of the Delta.

This concept is important for the CA Department of Water Resources' Dayflow program (http://www.water.ca.gov/dayflow/). The definition of the Sacramento inflow location in the Dayflow program, which is used to calculate Delta Outflow and OMR should not be changed, in order for comparisons of pre- and post-project to be done without confusion. In addition, this provides clarity in reporting the total export from the Delta from both the Sacramento and San Joaquin rivers. Once the NDD facility is operational, an additional term, NDD, the amount exported from the NDD facility, must be added to the Dayflow suite of calculations. The addition of the NDD term will be very straightforward to include since this program is simply a water mass balance calculation.

Memorandum

Date:	April 18, 2016
To:	Independent Review Panel, 2016 California WaterFix Aquatic Science Peer Review
From:	Marin Greenwood, ICF
Subject:	**Request for graphical representation of the effects on Sacramento flow of the rules for water diversion and the amount of water that will be diverted from the North Delta (Specific panel request #1)**

Introduction

This memorandum addresses the following specific request for information and materials:

1. *Request for graphical representation of the effects on Sacramento flow of the rules for water diversion & the amount of water that will be diverted from the North Delta.*
    a. *The long tables in Ch. 3 are too complicated to easily grasp.*
    b. *Request for hydro period graphs that simply capture the differences in relative water diversion from the Sacramento by the dual conveyance facility*
        i. *For a dry, average, wet, and extremely dry water year, provide the amount (cfs) of water that will be diverted each month. This should be presented in a series of graphs with month on the x-axis. A range in the diversion should be presented to reflect the various decisions that affect water diversion.*
        ii. *On the same hydrograph, show the diversion as a percentage of total water available in the Sacramento River at the diversion site*
    c. *For the same scenarios as the diversion at the dual conveyance facility, provide hydrographs for the Sacramento River below the diversion site, such as at Rio Vista or in the Cache Slough complex*
    d. *If reasonable, for the same scenarios above, show the position of X2?*

The memorandum includes information regarding the bypass flows as proposed and modeled, in addition to the above specific hydro period requests.

Bypass Flow Criteria

The Independent Science Panel found the tables explaining North Delta Diversion (NDD) bypass flow criteria (i.e., Tables 3.3-1 and 3.3-2 in the working draft Biological Assessment) challenging to interpret. As an example graphical representation of these criteria, Figure 1 illustrates the potential diversions that would be possible based on the bypass flow criteria during December-April, which is a period of particular management importance for outmigrating juvenile salmonids (e.g., Winter-Run Chinook Salmon). Note that other regulatory constraints affect the actual bypass flows (e.g., downstream water quality requirements), so that the actual percentage of flow diverted does not necessarily correspond to the amount allowable from the bypass flow criteria alone. This is illustrated in Figure 2 below. The regulatory criteria often controlling Delta operations are contained in the State Water Resources Control Board's (SWRCB) 2006 Water Quality Control Plan (WQCP) for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary , commonly referred to as D-1641 for the SWRCB's Water Right Decision 1641 from which the objectives were derived.[1] Among these criteria, which are intended to benefit a variety of in-Delta user groups, are flow and operational criteria intended to provide reasonable protection of fish and wildlife beneficial uses. It is important to note that the California WaterFix proposes to adhere to these objectives, as described in Chapter 3 of the working draft BA. Select important flow-based criteria from the WQCP are shown in Table 1. These provide important context for the specific hydro period graphs included in response to the Independent Science Panel's request.

Requested Hydro Period Graphs

The Independent Science Panel's request for representative hydro period graphs is addressed below based on CalSim-II modeling outputs of the proposed California WaterFix action scenario (proposed action, or PA) and, for context, the no action alternative (NAA). As described in the presentation to the panel, caution should be applied when examining individual years from CalSim-II outputs, for the purpose of the model is to provide longer term, planning-level comparisons (e.g., averages by water year types). In addition to the material requested by the panel, it is important to provide context for overall operational changes under WaterFix by also considering the role of south Delta exports. This is shown below in additional plots.

The selected example years were chosen by examining the mean water year (February-January, per the CalSim-II modeling) Sacramento River at Freeport flow. The following years were selected:

- Extremely dry year: the critically dry year of 1924 (mean Freeport flow = 9,345 cfs) (Figures 3 and 4)

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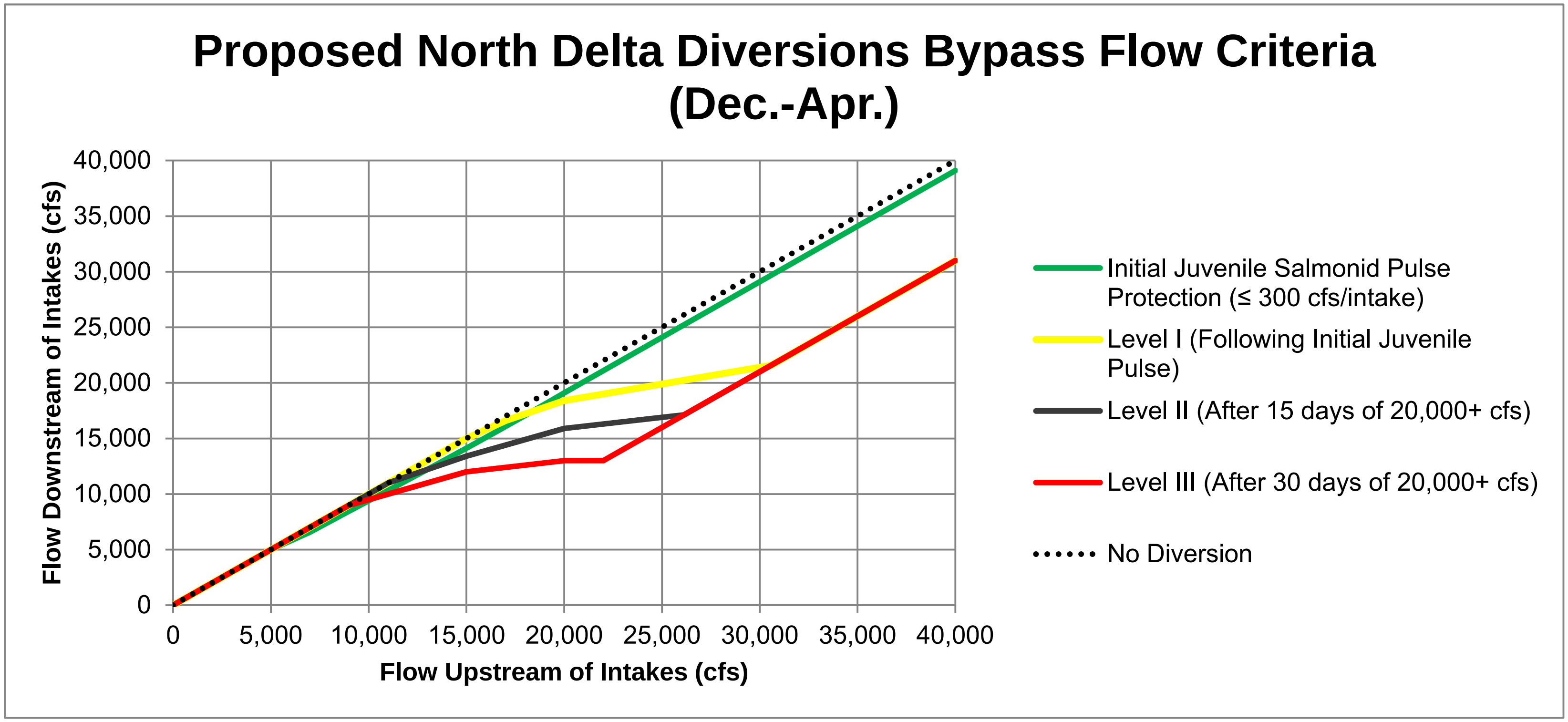
[1] State Water Resources Control Board. 2006. Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. December 13. Division of Water Rights, State Water Resources Control Board, Sacramento, CA. Available: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/2006wqcp/index.shtml

- Dry year: 1989 (mean Freeport flow = 16,003 cfs) (Figures 5 and 6)
- Average year: the below normal year of 1968 (mean Freeport flow = 21,927 cfs) (Figures 7 and 8) and the above normal year of 1980 (mean Freeport flow = 21,768 cfs) (Figures 9 and 10)
- Wet year: 1996 (mean Freeport flow = 36,368 cfs) (Figures 11 and 12)

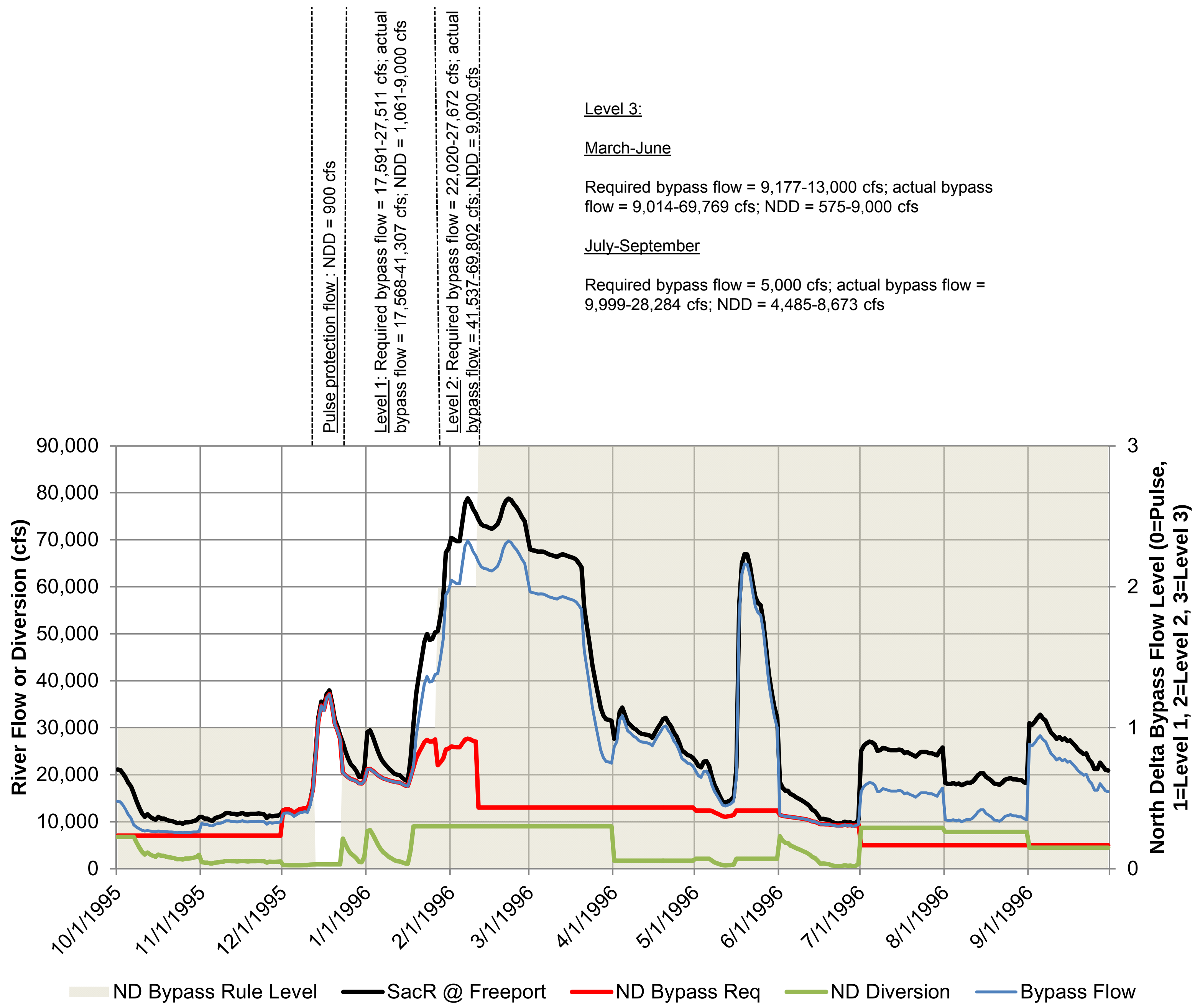
Each example year has two plots below, per the panel request and also to provide the important context for the effects of dual conveyance operations. The first plot includes the mean monthly water flow exported by the NDD, in addition to the percentage of Sacramento River flow upstream of the NDD (at Freeport) that this flow represents. The first plot's export flow axis is scaled to 10,000 cfs in order to allow the different years to be easily compared, in relation to the maximum possible 9,000-cfs diversion. Also included on the first plot is the export to inflow (E:I) ratio, which is a measure of water exported divided by water inflowing to the Delta. This ratio is included to recognize that with implementation of dual conveyance, a certain amount of export pumping would be shifted from the south Delta to the north Delta, so that south Delta exports under the PA would appreciably less than under the NAA. As noted on the first plot, the inflow (I) term for the PA is the Sacramento River downstream of the NDD (i.e., accounting for the water exported by the NDD); NDD exports are not included in the export (E) term for the PA (Figures 3,5,7,9,11).

The second plot for each example year includes the mean monthly flow in the Sacramento River at Rio Vista (for PA, as requested) and X2, the position of the 2-ppt near-bottom isohaline, with X2 shown for both the PA and NAA scenarios in order to emphasize that X2 is dependent on both south and north Delta exports. SWRCB WQCP outflow-based objectives occur year-round for the reasonable protection of fish and wildlife beneficial uses (Table 1); these are met under the PA and NAA (Figures 4, 6,8,10, 12).



Source: Adapted from Greenwood and Chilmakuri (2014: http://www.eposters.net/pdfs/habitat-restoration-and-water-diversion-effects-of-the-proposed-bay-delta-conservation-plan-on-the.pdf)

Figure 1. Proposed North Delta Diversions Bypass Flow Criteria (December-April example).

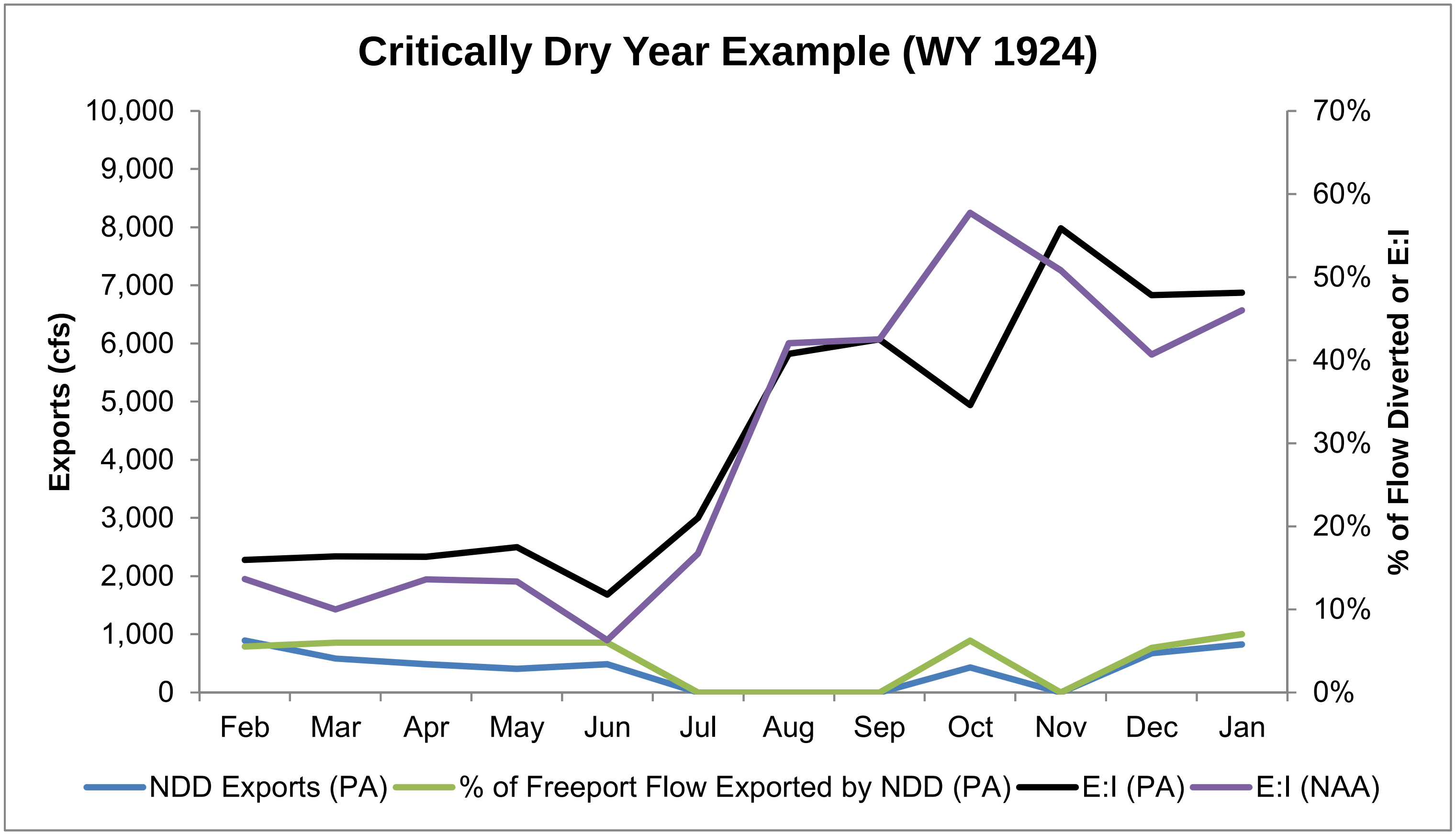


Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment. Note: the grey shading indicates the bypass rule (0=pulse/low level pumping, 1=level I, 2=level II, and 3=level III). 'SacR @ Freeport' = flow upstream of the NDD. 'ND Bypass Req' = the required bypass flow based on the criteria/rules (see Tables 3.3-1 and 3.3-2 in the working draft Biological Assessment). 'ND Diversion' is the water exports by the NDD. 'Bypass Flow' is the flow that was modeled to have been bypassed (i.e., occurred just downstream of) the NDD.

Figure 2. Example Year Daily Patterns and Operation of the North Delta Diversions

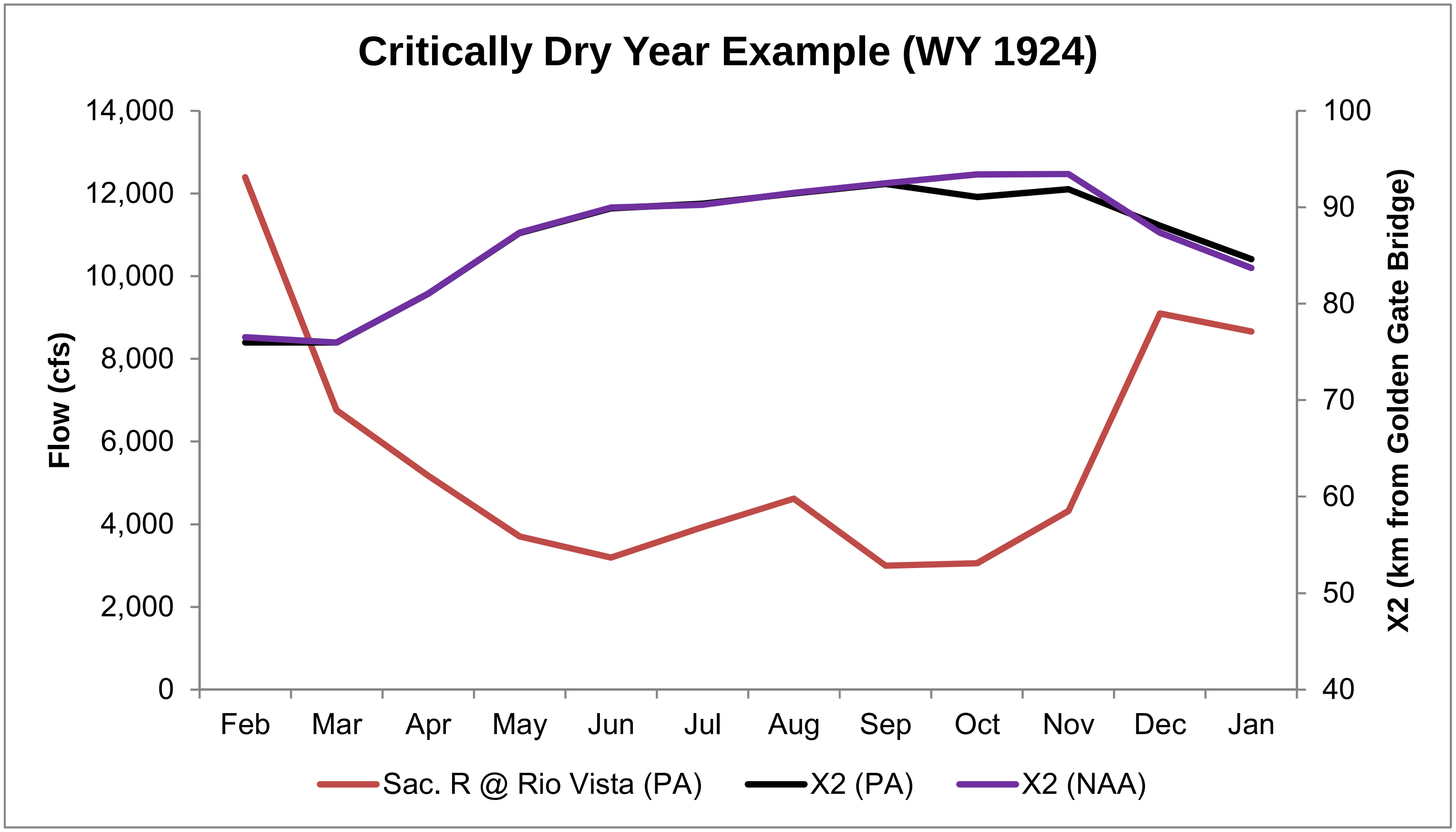
Table 1. Selected Flow-Related Water Quality Objectives for Fish and Wildlife Beneficial from the SWRCB (2006) Bay-Delta Water Quality Control Plan.

<table>
<tr><th>Objective</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>SWP/CVP Export Limits</td><td colspan="3"></td><td colspan="2">1,500 cfs</td><td colspan="7"></td></tr>
<tr><td>Export/Inflow (E:I) Ratio</td><td>0.65</td><td colspan="5">0.35</td><td colspan="6">0.65</td></tr>
<tr><td>Min. Delta Outflow</td><td>4,500-6,000 cfs</td><td colspan="5"></td><td colspan="6">3,000-8,000 cfs</td></tr>
<tr><td>Habitat Protection Outflow</td><td></td><td colspan="5">7,100-29,200 cfs</td><td colspan="6"></td></tr>
<tr><td>Rio Vista Flows</td><td colspan="8"></td><td colspan="4">3,000-4,500 cfs</td></tr>
</table>



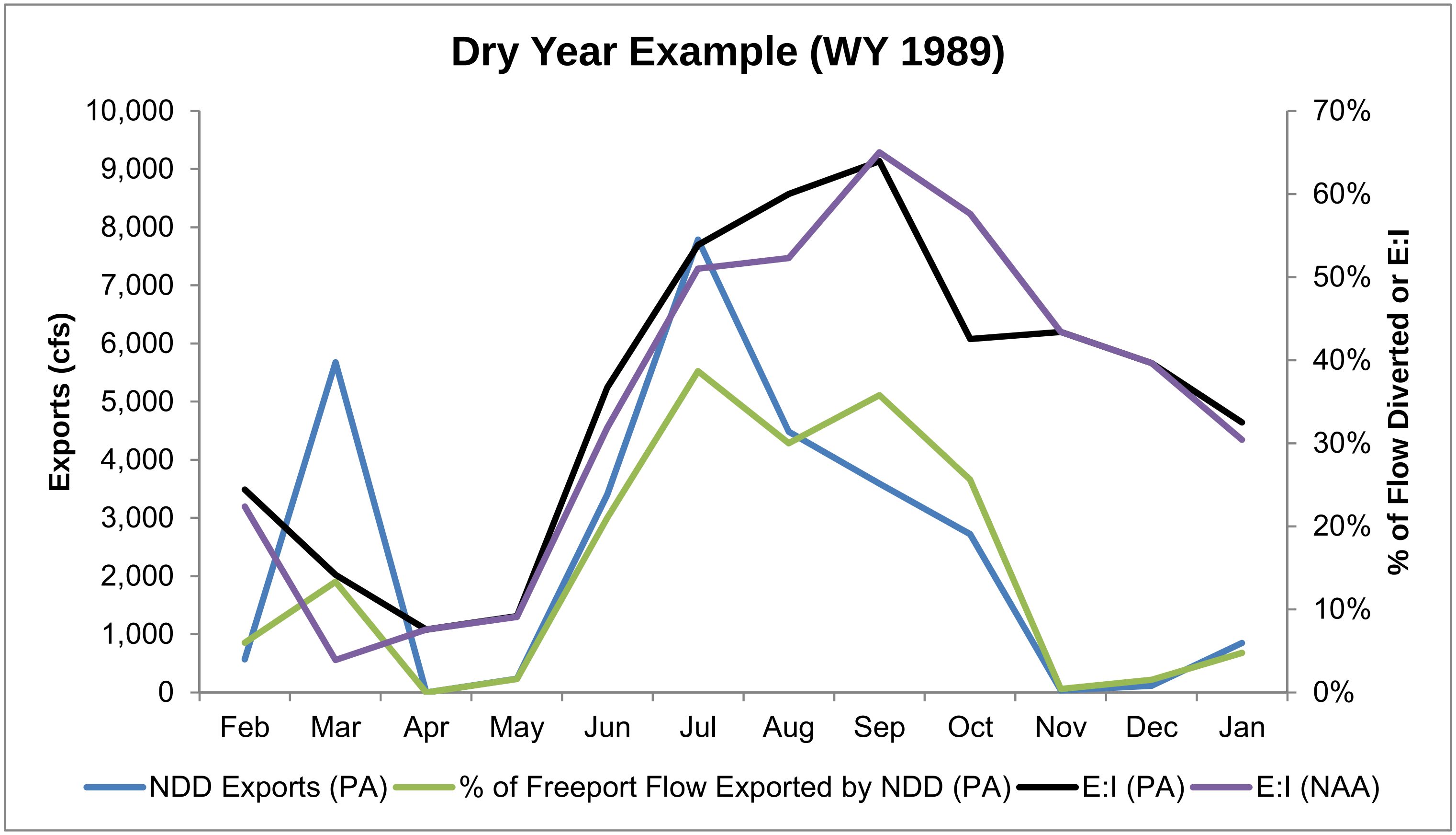
Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment. Note: E:I = exports to inflow ratio; the inflow (I) term for the PA is the Sacramento River downstream of the NDD; NDD exports are not included in the export (E) term for the PA.

Figure 3. Modeled Mean Monthly Exports by the North Delta Diversions and Percentage of Sacramento River at Freeport Flows Represented by these Exports, Water Year 1924.



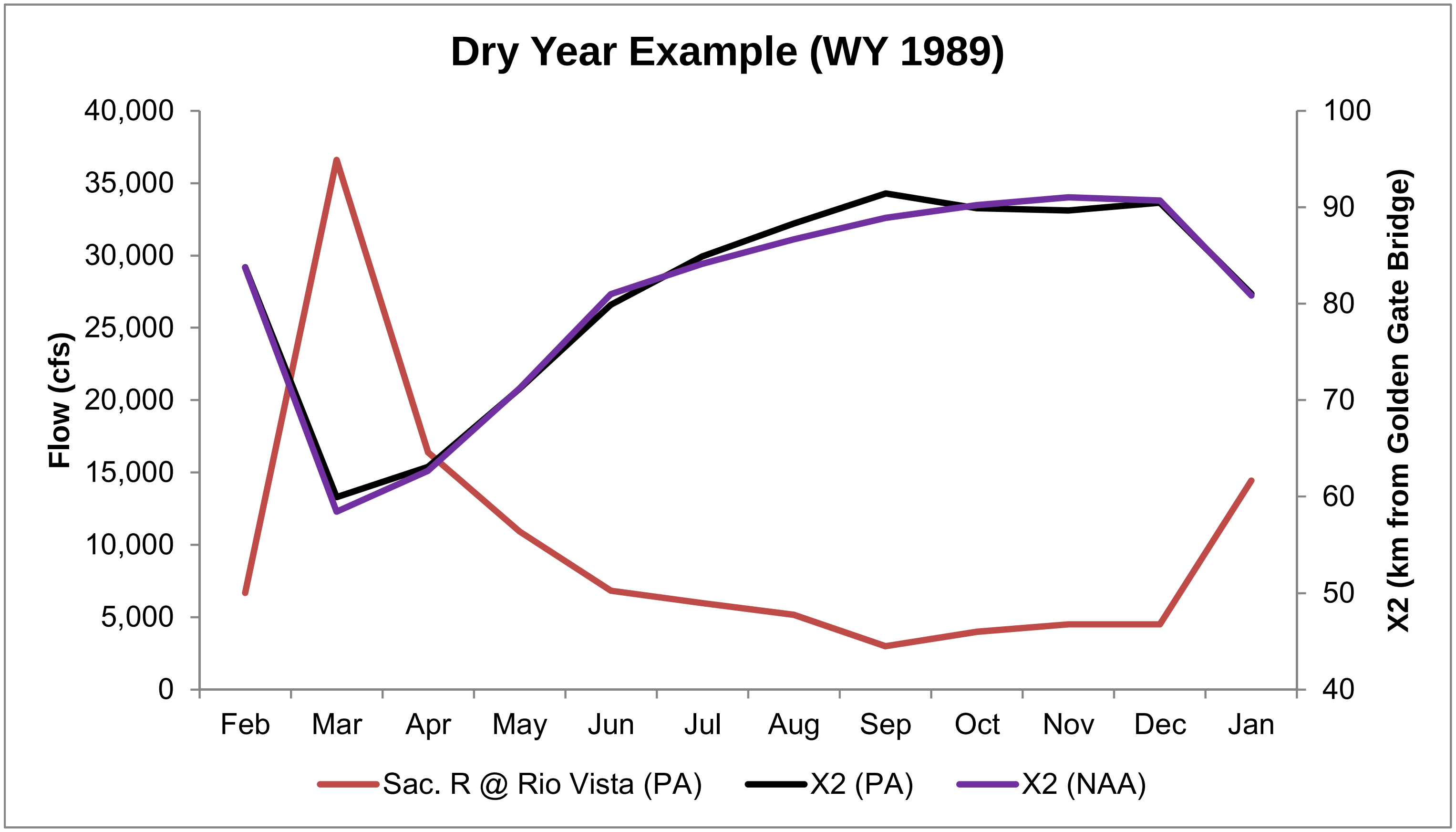
Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment.

Figure 4. Modeled Mean Monthly Sacramento River Flow at Rio Vista and X2, Water Year 1924.



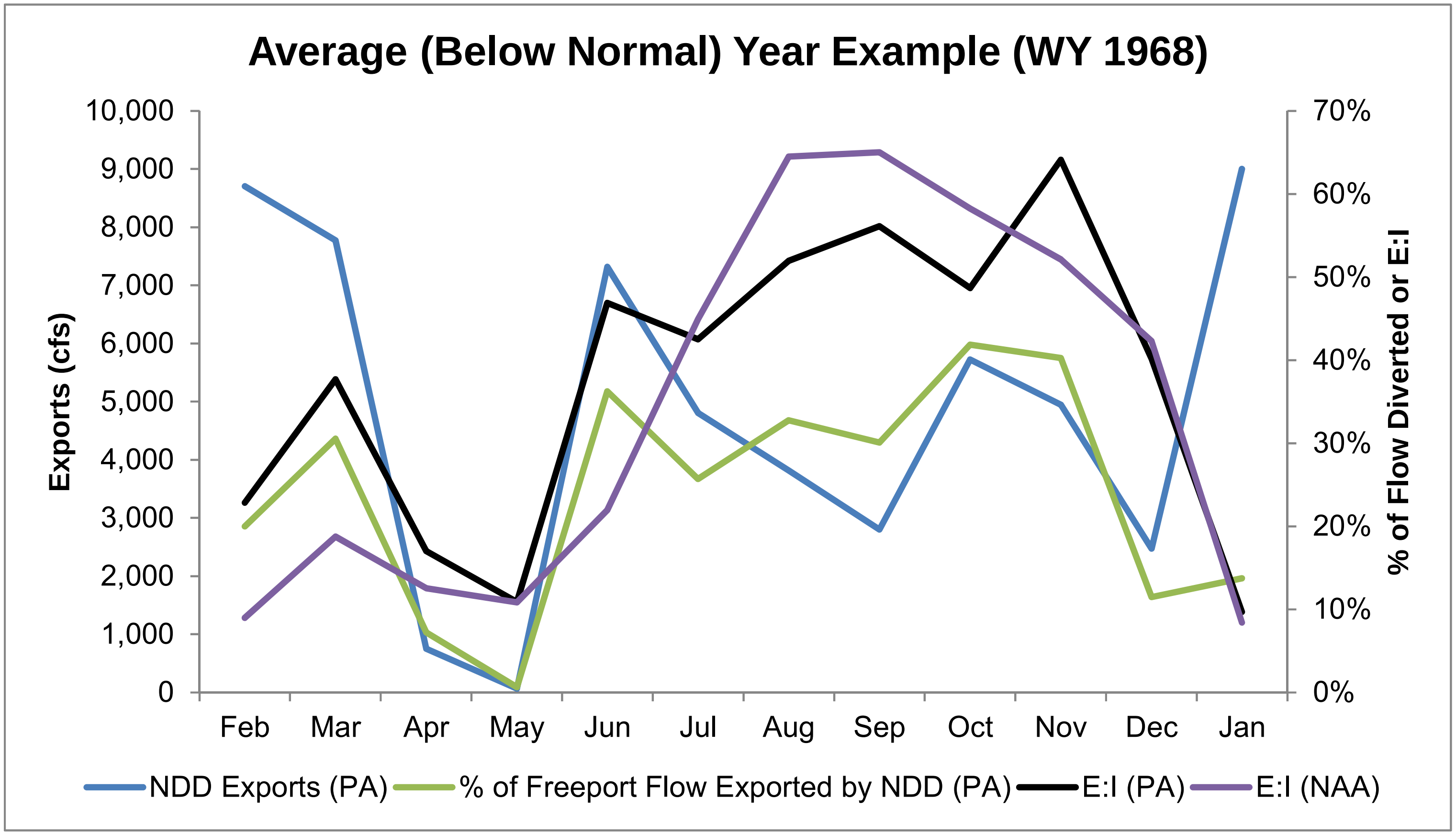
Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment. Note: E:I = exports to inflow ratio; the inflow (I) term for the PA is the Sacramento River downstream of the NDD; NDD exports are not included in the export (E) term for the PA.

Figure 5. Modeled Mean Monthly Exports by the North Delta Diversions and Percentage of Sacramento River at Freeport Flows Represented by these Exports, Water Year 1989.



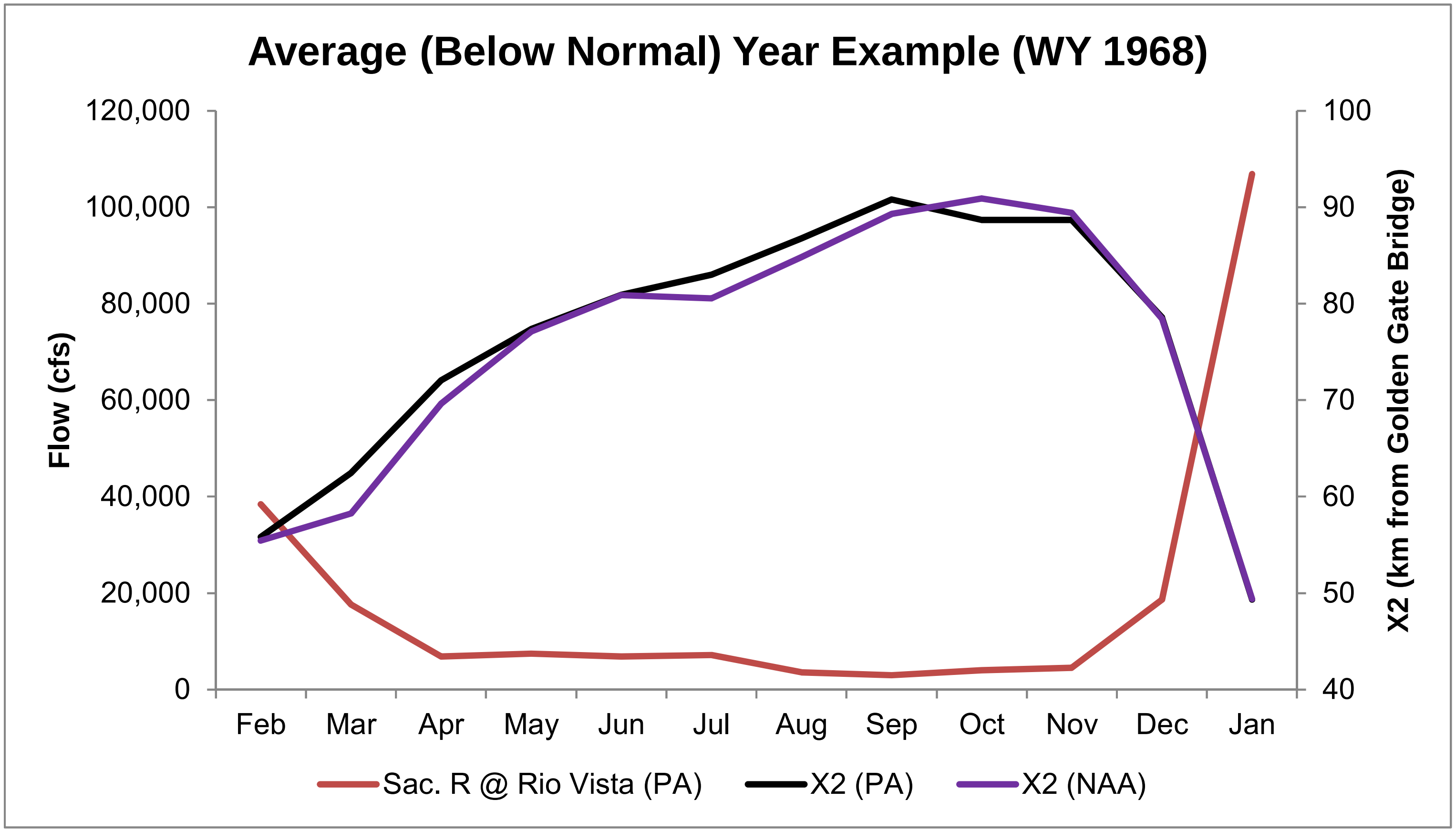
Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment.

Figure 6. Modeled Mean Monthly Sacramento River Flow at Rio Vista and X2, Water Year 1989.



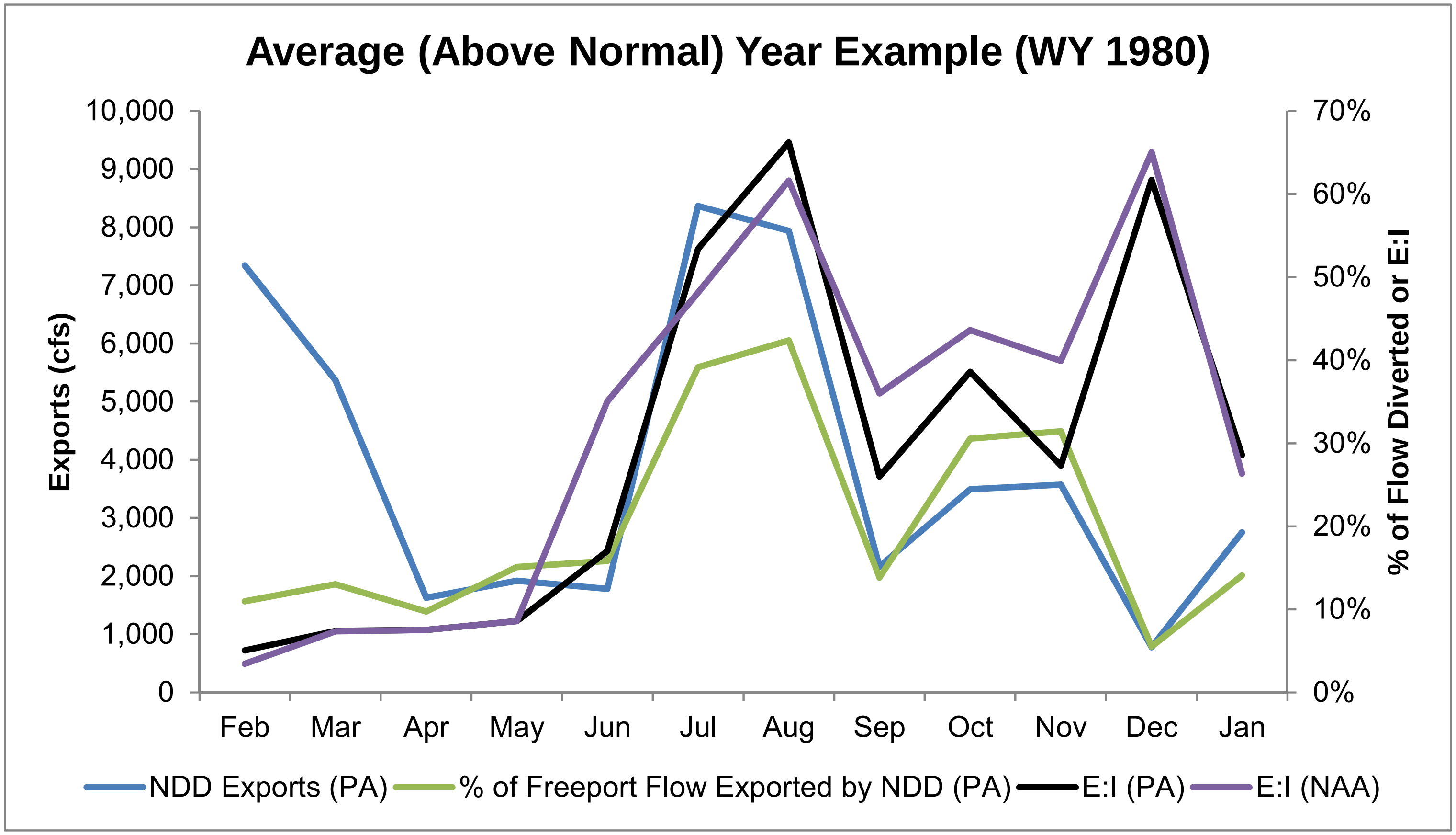
Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment. Note: E:I = exports to inflow ratio; the inflow (I) term for the PA is the Sacramento River downstream of the NDD; NDD exports are not included in the export (E) term for the PA.

Figure 7. Modeled Mean Monthly Exports by the North Delta Diversions and Percentage of Sacramento River at Freeport Flows Represented by these Exports, Water Year 1968.



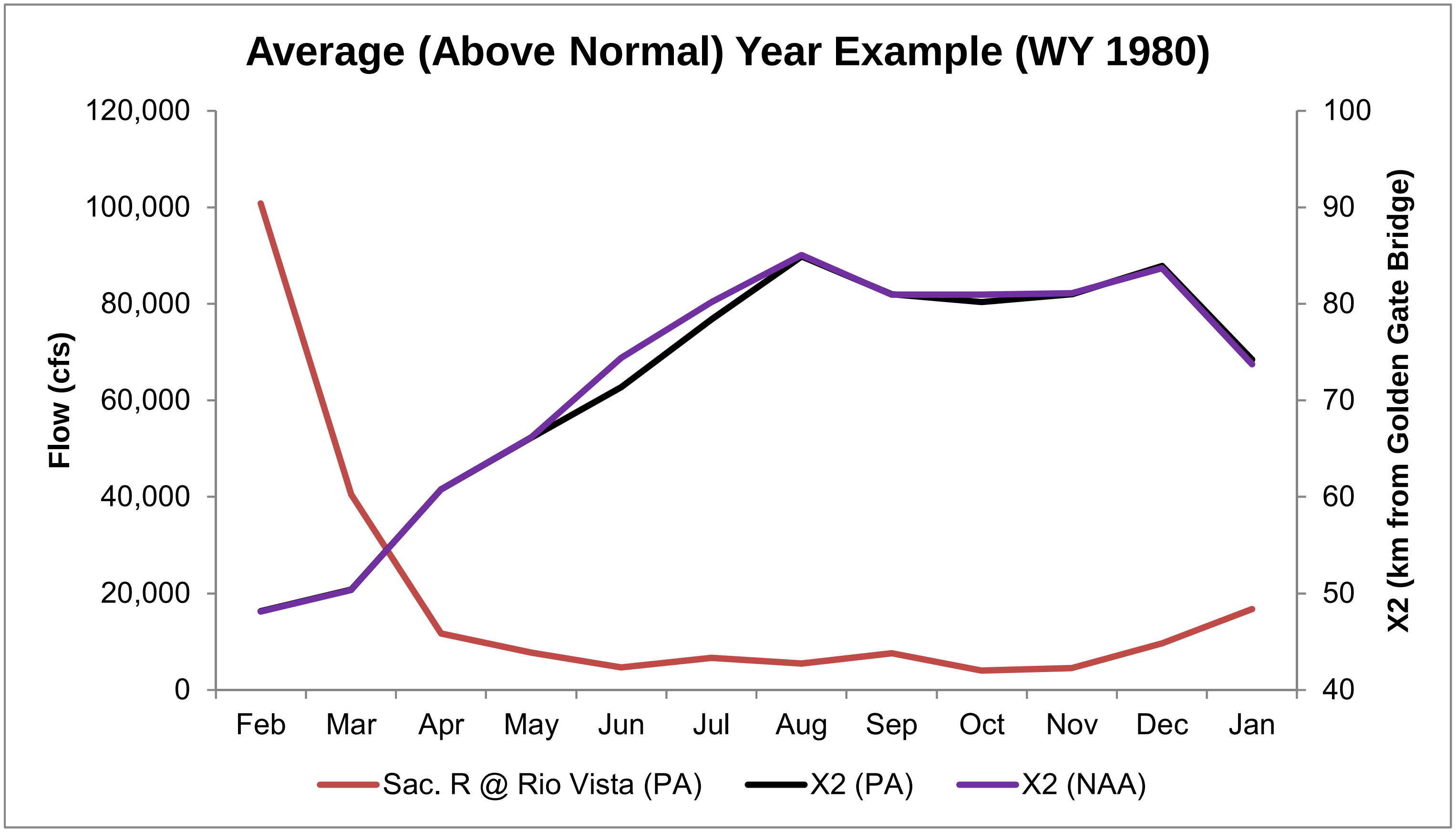
Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment.

Figure 8. Modeled Mean Monthly Sacramento River Flow at Rio Vista and X2, Water Year 1968.



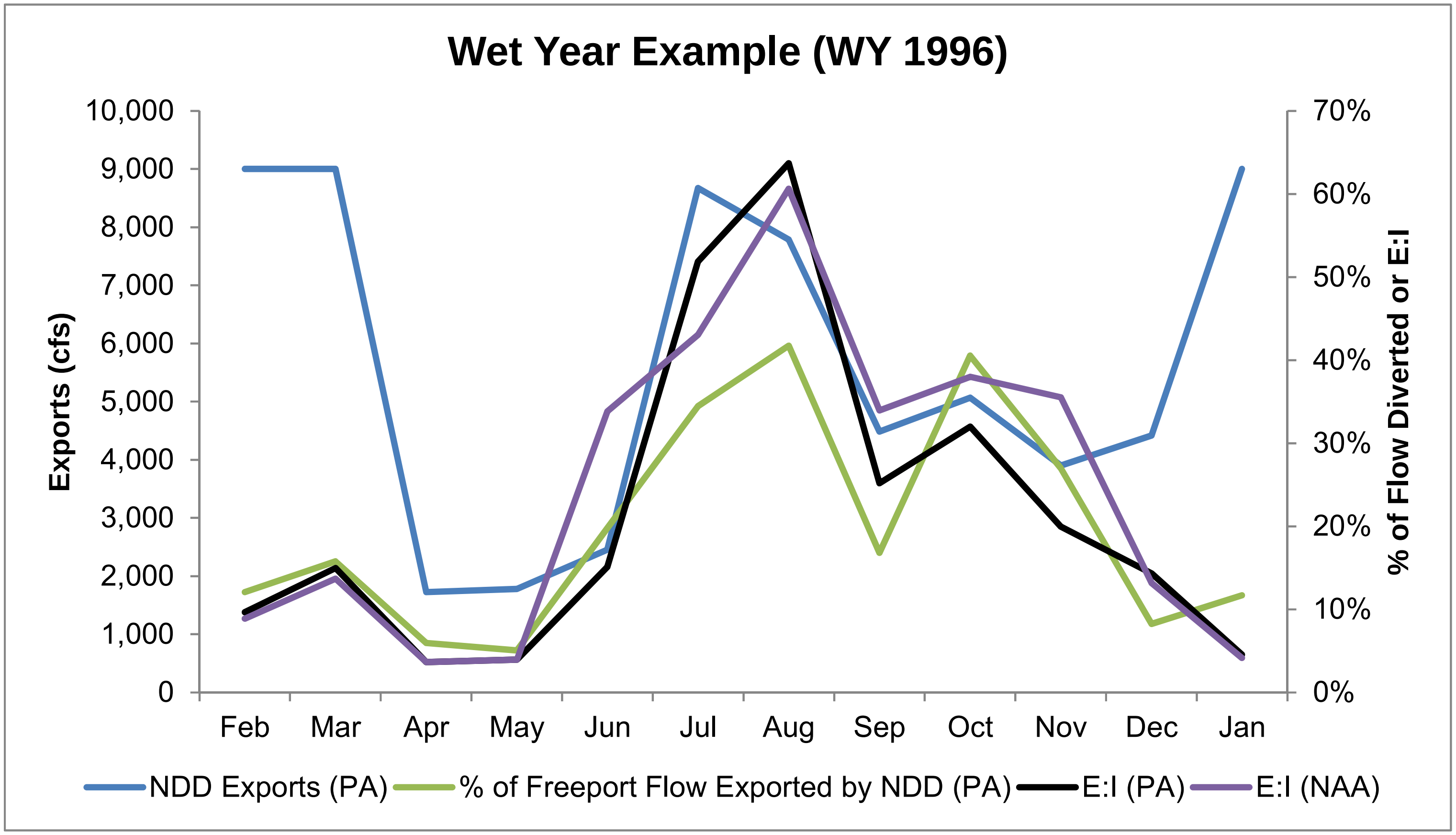
Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment. Note: E:I = exports to inflow ratio; the inflow (I) term for the PA is the Sacramento River downstream of the NDD; NDD exports are not included in the export (E) term for the PA.

Figure 9. Modeled Mean Monthly Exports by the North Delta Diversions and Percentage of Sacramento River at Freeport Flows Represented by these Exports, Water Year 1980.



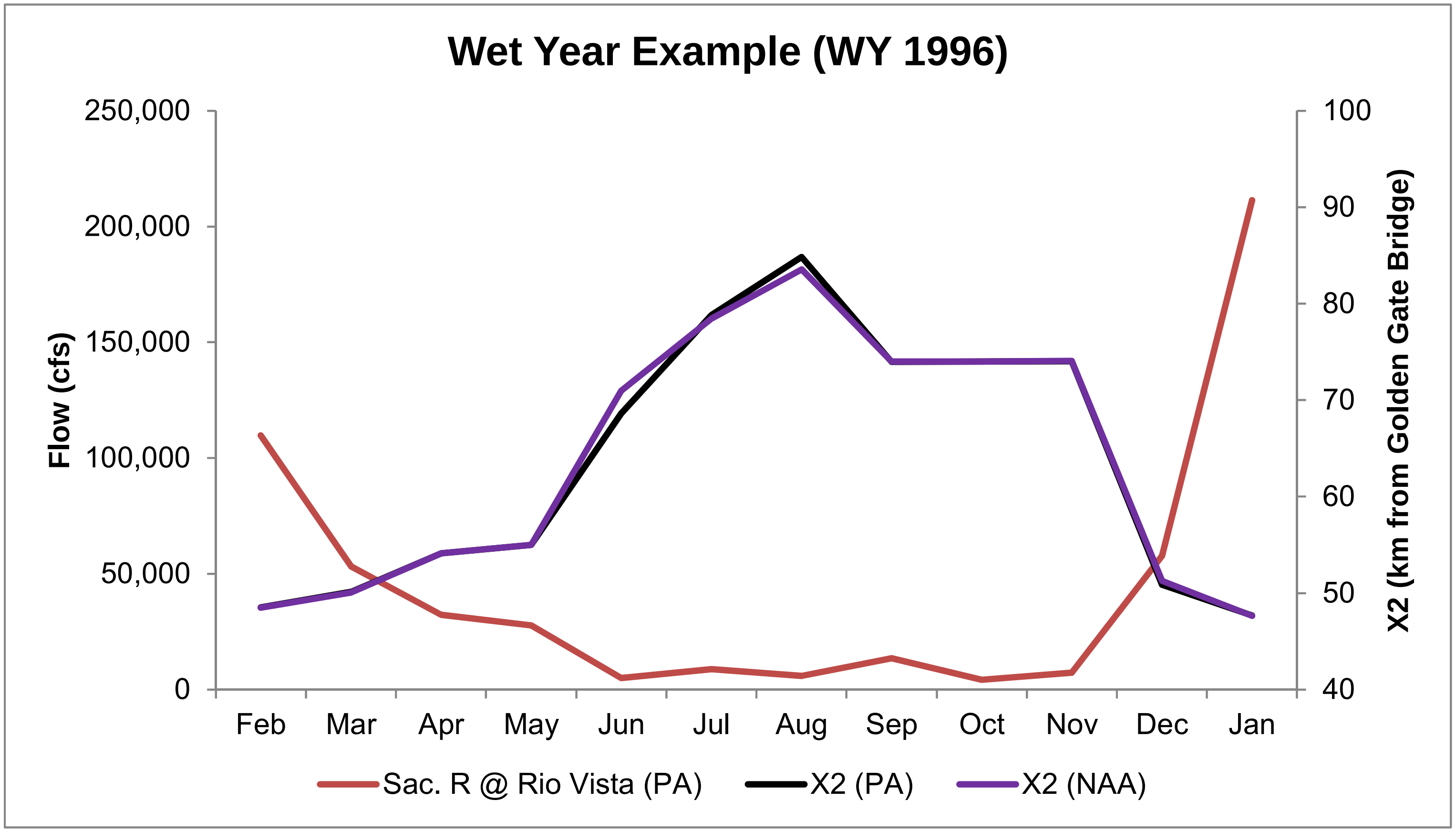
Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment.

Figure 10. Modeled Mean Monthly Sacramento River Flow at Rio Vista and X2, Water Year 1980.



Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment. Note: E:I = exports to inflow ratio; the inflow (I) term for the PA is the Sacramento River downstream of the NDD; NDD exports are not included in the export (E) term for the PA.

Figure 11. Modeled Mean Monthly Exports by the North Delta Diversions and Percentage of Sacramento River at Freeport Flows Represented by these Exports, Water Year 1996.



Source: Created by ICF from CalSim-II modeling undertaken for the working draft Biological Assessment.

Figure 12. Modeled Mean Monthly Sacramento River Flow at Rio Vista and X2, Water Year 1996.