Spencer Kenner (SBN 148930)
James E. Mizell (SBN 232698)
Robin McGinnis (SBN 276400)
DEPARTMENT OF WATER RESOURCES
Office of the Chief Counsel
1416 9th St., Room 1104
Sacramento, CA 95814
Telephone: 916-653-5966
E-mail: jmizell@water.ca.gov

Attorneys for California Department of Water Resources

BEFORE THE

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

HEARING IN THE MATTER OF CALIFORNIA DEPARTMENT OF WATER RESOURCES AND UNITED STATES BUREAU OF RECLAMATION REQUEST FOR A CHANGE IN POINT OF DIVERSION FOR CALIFORNIA WATER FIX

TESTIMONY OF MARIN GREENWOOD

I, Marin Greenwood, do hereby declare:

I. INTRODUCTION

My name is Marin Greenwood and I am employed as a Senior Technical Specialist with ICF. I received a Bachelor of Science degree in Aquatic Bioscience from the University of Glasgow, UK, in 1996; a Master of Science degree in Applied Fish Biology from the University of Plymouth, UK, in 1997; and a PhD on The Fish Populations of the Lower Forth Estuary, Including the Environmental Impact of Cooling Water Extraction, from the University of Stirling, UK, in 2002. I am a Certified Fisheries Professional with the American Fisheries Society. I have been employed with ICF for nearly 9 years. My experience with ICF includes work on a number of planning, permitting, and research projects within the Delta. I began work on the California Department of Water Resources (DWR) Bay Delta Conservation Plan (BDCP) in 2011, with my primary role being aquatic ecologist responsible for writing much of the Delta[1]-related portions of the covered fish effects analysis for the draft BDCP, with a secondary role contributing to development and revision of the conservation plan related to covered fish. I also assisted with preparation of the Fish and Aquatic Resources chapter for the draft BDCP Environmental Impact Report/Environment Impact Statement, principally by identifying the methods to be used based on the draft BDCP, and reviewing draft sections. With the transition from BDCP to California WaterFix (CWF), I served as a lead fish biologist for the Endangered Species Act (ESA) Biological Assessment (BA) and the California Endangered Species Act (CESA) 2081(b) Incidental Take Permit Application, again my primary role being preparation of the Delta listed fish effects analyses. I assisted in preparation of the Fish and Aquatic Resources chapter for the Revised Draft EIR/Supplemental draft EIS (RDEIR/SDEIS) and Final EIR/S (2016 FEIR/S) for BDCP/CWF, including responding to comments, developing revisions to address comments, and ensuring consistency between EIR/S analyses and BA analyses. I prepared materials for consideration by the draft BDCP Effects Analysis Independent Science Review Panel (2011-2014) and the CWF Aquatic Science Peer Review Phases 1 and 2A peer-review panels (2016). Attached as Exhibit DWR-1001 is a true and correct copy of my Statement of Qualifications.

In October 2015 DWR and U.S. Bureau of Reclamation (Reclamation) (jointly Petitioners) petitioned the State Water Board for the addition of three new points of diversion on Petitioners' water rights permits. In testimony submitted in Part 1 of this hearing, the project was described as Alternative 4A with initial operational criteria that would fall within a range of operations described as H3 to H4. These operational criteria were described in the RDEIR/SDEIS. (Exhibit SWRCB-3.) For purposes of Part 2 of the hearing, including this testimony, the CWF project is described by Alternative 4A under an operational scenario described as H3+ that is set forth in the Final Environmental Impact

[1] 'Delta' in this context is essentially taken to mean the BDCP plan area, which included not only the legal Delta but associated adjacent areas such as Suisun Bay and Suisun Marsh. In this testimony, I generally refer to this as 'Delta and adjacent areas'.

Report/Environmental Impact Statement and supplemental information adopted by DWR through the issuance of a Notice of Determination in July 2017. (2017 Certified FEIR, collectively Exhibits SWRCB-102, SWRCB-108, SWRCB-109, SWRCB-110, SWRCB-111 and SWRCB-112.) **The adopted project is referred to as CWF H3+.** Additional information is also referenced in this testimony from documents released prior to July 2017, including the Alternative 4A described in the Final Environmental Impact Report/Environmental Impact Statement, Biological Assessment and the Biological Opinions, referred to herein as the FEIR/FEIS, BA and the BO respectively. Similarly, after July 2017 the California Department of Fish and Wildlife issued a 2081(b) Incidental Take Permit, which is referred to as the ITP. The interrelationship and use of these terms is further described in the testimony of Ms. Buchholz, Exhibit DWR-1010.

II. OVERVIEW OF TESTIMONY

A. EXECUTIVE-LEVEL OVERVIEW

Under the existing Delta water conveyance system, reasonable protection[2] of listed fish such as Delta Smelt and Longfin Smelt and listed Chinook Salmon and steelhead from entrainment by the south Delta water export facilities requires restrictions on pumping during the winter and spring. Construction and operation of three Sacramento River intakes (the North Delta Diversions, NDD) in the northern Delta under the CWF H3+ will maintain and potentially increase this existing reasonable protection by reducing south Delta exports, particularly in wetter years.

The CWF H3+ NDD will reasonably protect listed fish by screening to required standards of opening size, approach velocity, and sweeping velocity. An extensive pre- and post-construction study program will provide reasonable protection of listed fish by reducing

[2] Throughout my testimony, I describe various measures that will be included in the CWF for the protection of fisheries. For those species that are protected by the Endangered Species Act (ESA), the level of protection that I have analyzed is consistent with the requirements of the ESA, pertinent biological opinions and other applicable requirements, including the Fish and Game Code and Water Code, which I have determined also meets the standard for reasonableness. For those species that are not subject to the ESA, etc., my analysis only considers the standard of reasonableness regarding impacts on fish and wildlife.

uncertainty of the potential effects of the NDD on smelts and migrating juvenile salmonids to inform final screen design and adaptive management. The CWF H3+ NDD are outside the main range of Delta Smelt and Longfin Smelt and therefore are limited in their potential to cause adverse effects such as entrainment of larvae. However, there is a potential for restricted access of smelts to shallow water habitat upstream of the NDD and this potential effect will be mitigated with 1,750 acres of restoration.

The CWF H3+ will reasonably protect fish through operational criteria and real-time operations adjustments based on monitoring of fish occurrence. Existing reasonable operational protection of low salinity zone fall rearing habitat for Delta Smelt will be maintained and spring Delta outflow for Longfin Smelt will follow protective criteria developed in coordination with California Department of Fish and Wildlife (CDFW). Adaptive management will inform the need for additional operational criteria prior to, and following, the start of CWF H3+ operations. Habitat-related operational effects of the CWF will be mitigated, for example by reintroducing sediment entrained at the NDD and restoring channel margin habitat. Construction and operation of a Head of Old River gate under the CWF H3+ has the potential to improve Delta migration for salmonids from the San Joaquin River basin.

Construction of CWF facilities will be undertaken during in-water work windows that reasonably protect listed fish by avoiding or minimizing their overlap with potentially harmful activities. A suite of avoidance and minimization measures will be employed to reasonably protect fish that encounter construction activities. Habitat lost during construction will be mitigated through restoration prior to construction.

Criteria to reasonably protect listed fish from construction and operations of the CWF are also reasonably protective of unlisted salmonids and other fish of management concern.

B. OVERVIEW OF TESTIMONY OPINIONS

My testimony provides the basis for my opinion that the CWF H3+ is consistent with the requirements under the biological opinions and is reasonably protective of Delta Smelt and Longfin Smelt; the Delta-occurring life stages of listed Sacramento River winter-run Chinook Salmon, Central Valley spring-run Chinook Salmon, Central Valley steelhead, and Southern Distinct Population Segment of North American Green Sturgeon; unlisted salmonids and Pacific Salmon Essential Fish Habitat (EFH); and other unlisted species that were included in the draft BDCP and 2016 FEIR/S (White Sturgeon, Sacramento Splittail, and Pacific and River Lamprey). In addition, I discuss Delta-related effects on other aquatic species of primary management concern that were included in the FEIR/S (Striped Bass, American Shad, Largemouth Bass, Sacramento Tule Perch, Threadfin Shad, and Bay Shrimp). The evidence that I present is based on effects analyses and other relevant information included in the 2016 FEIR/S, the BA, the ITP Application, BOs issued by the US Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS), the ITP and associated Findings of Fact under CEQA and CESA issued by CDFW, and other materials as specifically referenced in my testimony. I also used the 2017 Certified FEIR, which summarizes in a single place information inclusive of the BA and presents the final approved project.

Effects analyses included in the 2016 FEIR/S, BA, ITP Application, and BOs reflect extensive collaboration, review, and feedback provided by USFWS, NMFS and DFW, as well as by DWR and Reclamation. Biological modeling methods used outputs from other models described in Mr. Reyes' testimony (Exhibit DWR-1016), such as CalSim-II and DSM2. Detailed descriptions of the biological models are available in the sources referenced in my testimony, and an overview of the biological models referenced in my testimony is provided in Section III(D) of my testimony. As noted in Mr. Munevar's testimony (Exhibit DWR-71), modeling results should be viewed comparatively, as opposed to as absolute predictions. In some cases, more than one model was used to analyze the same effect, in which case conclusions were reached based on the weight of evidence. The biological modeling has a limited ability to take into account real-time management decisions. (Exhibit DWR-71, pp. 10 – 11.) Real-time management decisions, based on fine-scale temporal and spatial monitoring of fish occurrence in the Delta, will provide additional protection for fish species. (see e.g., Exhibit SWRCB-106, NMFS BO, Appendix E.) An explanation of real-time operations is described in Mr. Miller's testimony. (Exhibit DWR-1011.)

My testimony discusses the results from several different operations modeling scenarios. When describing the results from the 2016 FEIR/S, I reference the results from modeling of H3 and H4. When describing the results from the BA, BOs, and ITP Application, the results are generally referring to the BA H3+ scenario, except as specifically noted. Mr. Reyes' testimony (Exhibit DWR-1016) summarizes the operational assumptions for H3, H4, BA H3+, and CWF H3+. A sensitivity analysis comparing the BA H3+ to CWF H3+ is included in the 2017 Certified FEIR (Exhibit SWRCB-108, p.129 to p.155) which, as summarized by Mr. Reyes (Exhibit DWR-1016) shows that the two scenarios are generally similar.

My testimony regarding aquatic species in the Delta is divided into three main parts, the first discussing Delta Smelt and Longfin Smelt; the second discussing the Delta life stages of winter-run and spring-run Chinook Salmon, steelhead, and Green Sturgeon, in addition to unlisted salmonids and Pacific Salmon EFH; and the third discussing the Delta life stages of unlisted fishes that were included[3] in the draft BDCP and 2016 FEIR/S, and other aquatic species of primary management concern that were included in the 2016 FEIR/S, such as Striped Bass. In the first part of my testimony, following a basic introduction to relevant aspects of Delta Smelt and Longfin Smelt status and biology, I provide several opinions:

- Construction effects from CWF H3+ will be avoided, minimized, and mitigated to reasonably protect Delta Smelt and Longfin Smelt;
- Implementing dual conveyance under CWF H3+ will maintain or potentially increase existing reasonable protection of Delta Smelt and Longfin Smelt from entrainment risk at the south Delta export facilities;

[3] These species were included for take coverage under the BDCP.

- The CWF H3+ NDD will reasonably protect Delta Smelt and Longfin Smelt through screening and habitat restoration mitigating potential restricted access to upstream areas;
- CWF H3+ will maintain existing reasonable protection of Delta Smelt fall rearing habitat;
- CWF H3+ will reasonably protect Longfin Smelt by implementing spring outflow criteria developed in coordination with the CDFW;
- Other changes in Delta habitat from CWF H3+ operations will be limited or mitigated in order to reasonably protect Delta Smelt.

The second part of my testimony follows a similar structure to the first, so that following a basic introduction to relevant aspects of winter-run and spring-run Chinook Salmon, steelhead, Green Sturgeon, and unlisted salmonid status and biology, I provide several opinions:

- Construction effects from CWF H3+ will be avoided, minimized, and mitigated to reasonably protect listed salmonids and Green Sturgeon;
- Implementing dual conveyance under CWF H3+ will maintain or potentially increase existing reasonable protection of listed salmonids and Green Sturgeon from entrainment risk at the south Delta export facilities;
- The CWF H3+ NDD will be screened and operated to meet salmonid protection standards and will be subject to numerous pre- and post-construction studies to provide reasonable protection of listed and salmonids and Green Sturgeon;
- CWF H3+ NDD bypass flow criteria, real-time operational adjustments, and mitigation will reasonably protect juvenile listed salmonids emigrating downstream in the Sacramento River;
- Construction and operation of a Head of Old River gate will reasonably protect San Joaquin River basin salmonids;
- CWF H3+ operations will limit or mitigate potential changes in habitat suitability to reasonably protect listed salmonids and Green Sturgeon;

- CWF H3+ avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect unlisted salmonids and Pacific Salmon Essential Fish Habitat.

The third part of my testimony relates to other unlisted fishes that were included in the draft BDCP and 2016 FEIR/S and other aquatic species of primary management concern included in the 2016 FEIR/S, such as Striped Bass[4], and discusses the following opinion:

- Avoidance and minimization measures, conservation measures and recommendations, and operational criteria generally will reasonably protect other unlisted fishes and other aquatic species of primary management concern from potential CWF H3+ effects in the Delta.

The final part of my testimony briefly provides an overview of the biological model methods referenced in my testimony. Additional detail on these models is provided in the sources referenced in footnotes in my testimony.

III. DISCUSSION OF TESTIMONY

A. DELTA SMELT AND LONGFIN SMELT

As previously noted, my testimony for Delta Smelt and Longfin Smelt first provides an overview of the species' biology, and then discusses my opinions regarding reasonable protection of the species during implementation of CWF H3+:

- Construction effects from CWF H3+ will be avoided, minimized, and mitigated to reasonably protect Delta Smelt and Longfin Smelt;
- Implementing dual conveyance under CWF H3+ will maintain or potentially increase existing reasonable protection of Delta Smelt and Longfin Smelt from entrainment risk at the south Delta export facilities;
- The CWF H3+ NDD will reasonably protect Delta Smelt and Longfin Smelt through screening and habitat restoration mitigating potential restricted access to upstream

[4] The full list of species was provided earlier in my testimony.

areas;

- CWF H3+ will maintain existing reasonable protection of Delta Smelt fall rearing habitat;
- CWF H3+ will reasonably protect Longfin Smelt by implementing spring outflow criteria developed in coordination with the CDFW;
- Other changes in Delta habitat from CWF H3+ operations will be limited or mitigated in order to reasonably protect Delta Smelt.

1. OVERVIEW OF DELTA SMELT AND LONGFIN SMELT STATUS AND BIOLOGY

a. Delta Smelt

A status and biology overview for Delta Smelt is provided in the FEIR/S (Exhibit SWRCB-102), Chapter 11, Appendix 11A (pp. 11A-1 - 11A-27) and ITP Application (Exhibit DWR-1036, pp. 2-1 to 2-10), from which, as well as from other sources, I summarize some main relevant points. Delta Smelt are small (typically no more than 70-80 millimeters long as adults), translucent fish that are endemic to the San Francisco Estuary. The general life cycle of Delta Smelt is shown in Figure 5 of Exhibit DWR-1089.[5]

As described in the USFWS BO (Exhibit SWRCB-105, p. 141-142),[6] "Each year, the distribution of delta smelt seasonally expands when adults disperse in response to winter flow increases that also coincide with seasonal increases in turbidity and decreases in water temperature. The annual range expansion of adult delta smelt extends up the Sacramento River to about Garcia Bend in the Pocket neighborhood of Sacramento, up the San Joaquin River from Antioch to areas near Stockton, up the lower Mokelumne River system, and west throughout Suisun Bay and Suisun Marsh. Some delta smelt seasonally and transiently occupy Old and Middle river in the south Delta each year, but face a high

[5] Note that Figure 5 of Exhibit DWR-1089 does not represent the freshwater-resident portion of the population found year-round in the north Delta, or the portion of the population occurring in the Napa River.

[6] Citations are omitted here, but are provided in the USFWS BO (Exhibit SWRCB-105).

risk of entrainment when they do. The distribution of delta smelt occasionally expands beyond this area. For instance, during high outflow winters, adult delta smelt disperse west into San Pablo Bay and up into the Napa River. Similarly, Delta Smelt have occasionally been reported from the Sacramento River north of Garcia Bend up to Knights Landing. Recent analyses suggest that after an initial dispersal in December, the adult Delta Smelt population does not respond strongly to variation in Delta outflow during January to May, though some individuals continue to move around in response to flow changes associated with storms set." Spawning predominantly occurs in fresh water in spring, and some larvae/juveniles move downstream to rear and mature in the low salinity zone in summer and fall. A portion of the Delta Smelt population remains year-round in fresh water areas with suitable conditions, such as the north Delta in the vicinity of Cache Slough including Liberty Island, and the Sacramento Deep Water Ship Channel.

Delta Smelt is primarily an annual species; most adult Delta Smelt are believed to die after spawning, but some survive to live for a second year and spawn again as 2-year-olds. The general timings for the various life stages were provided in the USFWS BO (Exhibit SWRCB-105, pp. 229-234) as December-March for migrating adults, February-June for spawning adults, March-June for eggs/embryos and transport of larvae/early juveniles downstream, and July-December for rearing juveniles. In addition to movement upstream from the low salinity zone to spawn in the Delta, spawning can occur by movement into areas such as Suisun Marsh.

Delta Smelt are listed as threatened under the ESA[7] and as endangered under CESA. Designated critical habitat under the ESA includes the legal Delta and Suisun Bay/Suisun Marsh, and has several Primary Constituent Elements (PCEs; as summarized from the USFWS BO (Exhibit SWRCB-105, pp. 168 to 171): PCE 1 is the structural components of habitat, generally summarized as habitat for spawning (primarily thought to be sandy substrates) and open-water habitat with depth variation giving shallow, slower

[7] USFWS found that listing as endangered is warranted but precluded by higher priority listing actions.

current, and turbid areas; PCE 2 is water of suitable quality, low in contaminants, which includes suitable levels of turbidity, water temperature, and food in particular; PCE 3 is river flow facilitating movement of Delta Smelt and influencing the extent of spawning habitat availability; and PCE 4 is salinity, in particular the extent of the low salinity zone (salinity below 6 parts per thousand), for which Delta outflow determines the extent and overlap of low salinity with shallower areas of relatively high turbidity and low current speed.

Available survey data suggest that the species is at very low abundance compared to historic levels. Among the environmental factors hypothesized to affect the status of the Delta Smelt population are entrainment by water diversions, rearing habitat extent, water temperature, declines in turbidity, declines in food abundance, contaminants, and predation. Statistical analyses have found differing levels of evidence for the importance of these various factors; for example, the USFWS BO (Exhibit SWRCB-105, p. 134) suggested that water temperature and changes in food abundance are the only factors that are 'universally supported' by the various statistical analyses, and that examination of other factors has led to differing conclusions.

b. Longfin Smelt

The status and biology of Longfin Smelt is reviewed in the FEIR/S, Appendix 11A (Exhibit SWRCB-102, pp. 11A-27 to 11A-42) and in the ITP Application (Exhibit DWR-1036, pp. 2-10 - 2-12, and Appendix 2.A), which form the main basis for the summary I provide herein. In contrast to Delta Smelt, the Longfin Smelt life span is primarily two years, with fish reaching about 90-110 millimeters long as adults.

The fall midwater trawl Longfin Smelt abundance index has been very low in recent years. Adult Longfin Smelt generally migrate to spawning areas in late fall/early winter. Spawning peaks in January/February and occurs in fresh and brackish water, which is generally found between the Delta and Suisun Bay, but can include other areas within the Bay-Delta depending on hydrologic conditions. Most larvae surviving to later life stages appear to rear at low salinity (around 2 parts per thousand), with fewer individuals surviving from fresh (considerably less than 1 part per thousand) or brackish (greater than 4 parts per thousand).[8] Larval distribution in winter/early spring is mostly between the West Delta and San Pablo Bay, although the distribution generally shifts upstream or downstream depending on Delta outflow. Juveniles appear to prefer cooler and deeper water in the summer months, and therefore move seaward, west of Suisun Bay, into San Pablo Bay, central and south San Francisco Bay; some also apparently move to the coastal ocean. Some 1-year-olds move upstream in the late fall/early winter, at the same time as 2-year-old adults are migrating to spawning areas.

Environmental factors hypothesized to affect the status of the Longfin Smelt population include: entrainment by water diversions, reduced freshwater flow, water temperature, declines in turbidity, declines in food abundance, contaminants, and predation, as well as bycatch in the bay shrimp fishery. (See Exhibit SWRCB-102, Chapter 11, Appendix 11A, pp. 11A-32-11A-36; Exhibit DWR-1036, Appendix 2.A, pp. 2.A.1-7 - 2.A.1-10.) Statistical analyses have found strong links between winter/spring outflow and Longfin Smelt abundance, although the mechanisms for the relationship remain uncertain.

Other aspects of Delta Smelt and Longfin Smelt biology that are relevant to support my opinion that there is reasonable protection from potential CWF H3+ effects are provided as necessary in the following opinions.

2. CONSTRUCTION EFFECTS FROM CWF H3+ WILL BE AVOIDED, MINIMIZED, AND MITIGATED TO REASONABLY PROTECT DELTA SMELT AND LONGFIN SMELT

In my opinion, the combination of in-water work windows to avoid species occurrence, environmental commitments, avoidance and minimization measures, conservation measures; and habitat mitigation will reasonably protect Delta Smelt and Longfin Smelt from CWF H3+ construction effects.

As described in the testimony of Mr. Bednarski (Exhibit DWR-57) in Part 1 of this

[8]Specifically, the analysis by Hobbs et al. (2010) as cited in Appendix 2.A of the ITP Application (Exhibit DWR-1036) compared categories of fresh (0 to 0.3 parts per thousand salinity), low salinity (0.4 to 3 parts per thousand), and brackish (greater than 4 parts per thousand); these categories are slightly different than those noted in Appendix 2.A of the ITP Application (i.e., less than 1 part per thousand; around 2 parts per thousand; and greater than 6 parts per thousand).

hearing, there are numerous in-water construction activities that will occur as part of the CWF H3+, including work on the NDD, Clifton Court Forebay (CCF), Head of Old River gate (HORG), and barge landings. The primary means to reasonably protect Delta Smelt and Longfin Smelt from potential construction effects is through the use of in-water work windows, which will avoid or minimize exposure of the two species to factors such as those listed in Impact AQUA-1 in pages 11-3172 to 11-3191 of the FEIR/S (Exhibit SWRCB-102) (i.e., temporary increases in turbidity, accidental spills, disturbance of contaminated sediments, underwater noise, fish stranding, permanent loss of habitat, and predation). The in-water work windows are component-specific and are described in the 2017 Certified FEIR (Exhibit SWRCB-108, p. 103), and the potential overlap with Delta Smelt and Longfin Smelt life stages is shown in the 2016 FEIR/S Table 11-7 (Exhibit SWRCB-102, Section 11.3.1.1, p. 11-203). In addition, during the overall June 1 through October 31 work window, Delta Smelt and Longfin Smelt are primarily downstream of construction, in the western Delta and downstream. (See e.g., Exhibit SWRCB-105, Figure 9.2.1.1-7, p. 141.) During the work window, Delta Smelt and Longfin Smelt may occur in low or very low numbers near construction areas in the north, east, and south Delta but only in June and possibly July. As described above, a portion of the Delta smelt population resides year-round in the north Delta near the Cache Slough area; however, these individuals are not expected to be affected by NDD construction activities during the in-water work window. Longfin Smelt move out of the Delta and into the Bay from approximately July through October.

During the June and July time period, the numerous Environmental Commitments, Avoidance and Minimization Measures, and Conservation Measures described in Appendix 3B of the 2016 FEIR/S (Exhibit SWRCB-102) will limit potential effects and provide reasonable protection of the species.

The 2016 FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2, pp. 11-3191 and 11-3203) concluded that construction effects on Delta Smelt and Longfin Smelt will not be adverse

(NEPA finding) and less than significant with mitigation for pile driving[9] (CEQA finding). This is consistent with the USFWS BO (Exhibit SWRCB-105, p. 245-246) assessment of the effects on Delta Smelt and the ITP Findings of Fact (Exhibit DWR-1095, pp. 290-291) that CWF H3+ construction effects will be minimized and fully mitigated.

Permanent loss of shallow water and tidal perennial habitat will occur as a result of construction of CWF H3+ facilities, including 500.6 acres related to the NDD,[10] 2.9 acres at the HORG, and 22.4 acres at the barge landings. The loss of shallow water habitat related to the NDD represents a relatively small proportion of overall shallow water habitat in areas occupied by Delta Smelt (Exhibit DWR-1090), particularly given that Delta Smelt occurrence in this area is relatively limited compared to other parts of the Delta and adjacent areas. Habitat loss will be mitigated by a total of nearly 1,828 acres of restoration (Exhibit SWRCB-108, pp. 107-108). As described in Condition of Approval 10.1 of the CWF ITP (Exhibit SWRCB-107, p. 211), DWR must implement this compensatory mitigation prior to initiating construction activities that impact Delta Smelt and Longfin Smelt habitat. DWR is required to coordinate with USFWS and CDFW during the process of site selection and restoration design for the habitat mitigation lands.

In light of the combination of in-water work windows, environmental commitments, avoidance and minimization measures, conservation measures, and habitat mitigation, it is my opinion that Delta Smelt and Longfin Smelt will be reasonably protected from CWF H3+ construction effects.

3. IMPLEMENTING DUAL CONVEYANCE UNDER CWF H3+ WILL MAINTAIN OR POTENTIALLY INCREASE EXISTING REASONABLE PROTECTION OF DELTA SMELT AND LONGFIN SMELT FROM ENTRAINMENT RISK AT THE SOUTH DELTA EXPORT FACILITIES

By implementing dual conveyance under the CWF H3+, there is less use of the

[9] Specifically, Mitigation Measure AQUA-1a requires minimal use of impact pile driving (potentially a cause of death or injury to fish), and Mitigation Measure AQUA-1b requires underwater noise to be monitored and attenuation devices to be used as necessary (Exhibit SWRCB-102, Section 11.3.4.2, pp. 11-302 and 11-303).

[10] This includes not only the footprint of the facilities, but also the potential restriction of upstream access, as discussed further in Section A.4 of this testimony.

south Delta export facilities, and therefore there is the potential for Delta Smelt and Longfin Smelt entrainment risk to be reduced from, or at least maintained no more than, the existing levels, which in my opinion are reasonably protective.

a. Delta Smelt

As described in the USFWS BO (Exhibit SWRCB-105, pp. 257-261), Delta Smelt are entrained into the SWP/CVP south Delta export facilities, with high prescreen loss rates, particularly in Clifton Court Forebay (CCF). Although salvage occurs for some fish that are screened by the louvers, the USFWS considers mortality to be 100% for these fish. Estimates of historic entrainment rates suggested high percentages of the Delta Smelt population were entrained in some years, although the population-level significance of the losses is uncertain. The USFWS (2008) and NMFS (2009) BiOps (2008/09 BiOps) have reduced the potential for entrainment loss since 2008–2009 through restrictions in south Delta export pumping to meet Old and Middle River flow criteria, in order to avoid jeopardy to listed fishes, including Delta Smelt. The CWF H3+ will maintain the protective criteria of the 2008/09 BOs (see e.g., Exhibit SWRCB-105, Table 9.9.4-1, pp. 178-185). Implementation of dual conveyance under CWF H3+ will further reduce the use of the south Delta export facilities, potentially reducing further the risk of entrainment for Delta Smelt as diversions are moved away from areas where Delta Smelt are more abundant.

The FEIR/S included quantitative analyses for adult and larval/juvenile Delta Smelt entrainment loss potential at the south Delta export facilities for the H3 scenario, based on regression equations originally used by USFWS (2008) in the SWP/CVP BO, which estimates the population proportion lost due to the hydrodynamic influence of the facilities (represented as average December-March Old and Middle River [OMR] flows from CalSim-II modeling) (Exhibit SWRCB-102 [Impact AQUA-3], Section 11.3.5.2, pp. 11-3192 to 11-3195.)[11]. The analysis indicated the potential for the percentage entrainment loss of Delta

[11] An overview of the method is provided in the FEIR/S Table 11-14 (Exhibit SWRCB-102, Section 11.3.2.1, p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.5 (p. 5B-67). Modeling is provided in Exhibit DWR-1074, file <FWS_prop_entrainment_regressions_ESO_HOS_LOS.xlsx>.

Smelt to be similar or lower under the CWF H3+ than with the no action alternative (NAA), with variable differences when the results are summarized by water year type. (Exhibit SWRCB-102, Section 11.3.5.2, Table 11-4A-2, p. 11-3193.) The FEIR/S analyses indicated effects to be not adverse/less than significant due to less south Delta pumping.

The USFWS BO (Exhibit SWRCB-105, pp. 262 and 321-322) evaluated Delta Smelt entrainment risk under the CWF H3+ by assessing the frequency of OMR flows greater than -2,000 cfs from CalSim-II modeling (BA H3+ scenario), which is a threshold expected to be protective of a high fraction of adult Delta Smelt because Sacramento River water flowing into the mainstem San Joaquin River is not being rapidly drawn into Old and Middle rivers. Overall, the USFWS BO (Exhibit SWRCB-105 p. 326) concluded that dual conveyance will reduce entrainment risk to Delta Smelt.

b. Longfin Smelt

The 2016 FEIR/S analyses of Longfin Smelt entrainment in south Delta SWP-CVP facilities were based on particle tracking modeling (PTM[12]) for larvae and the salvage-density method[13] for juveniles and adults. (Exhibit SWRCB-102 [Impact AQUA-21], Section 11.3.5.2, pp. 11-3204 - 11-3205.) These analyses in the 2016 FEIR/S were based on the H3 scenario and indicated the potential for reduced entrainment under the CWF H3+, and the impact was concluded to be not adverse/less than significant. As noted in the 2017 Certified FEIR (Exhibit SWRCB-108, p. 184), the ITP Application (Exhibit DWR-1036, Section 4.2.3.2 [Entrainment and South Delta Entry], beginning at p. 4-265) also used PTM[14] (updated from what was used in the 2016 FEIR/S) to evaluate larval entrainment

[12] An overview of the method is provided in the FEIR/S Table 11-14 (Exhibit SWRCB-102,Section 11.3.2.1, p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.5 (p.5.B-79). Modeling is provided in Exhibit DWR-1074, files <Longfin_Smelt_60d_PTM_results_collated_Marin.xlsx> and < LS PTM Results_60D_NewHydro_ESO(Alt4)_081712_ss_mk_ros_082012ss_mk.xlsx>.

[13] An overview of the method is provided in the FEIR/S Table 11-14 (Exhibit SWRCB-102,Section 11.3.2.1, p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.4 (p.5.B-59). Modeling is provided in Exhibit DWR-1074, files <Salvage_Longfin smelt 07072011.xlsm> and <Salvage_Longfin Smelt_WY07132011.xlsm>.

[14] A description of the method is provided in the ITP Application (Exhibit DWR-1036) Appendix

risk, as well as a salvage-OMR-flow regression[15] to predict juvenile Longfin Smelt salvage. Generally, these analyses of the BA H3+ scenario suggested reduced entrainment and salvage under the CWF H3+ compared to the NAA, except in late spring of drier water years, for which juvenile salvage was predicted to increase under the CWF H3+ due to HORG operations (see Exhibit DWR-1036, Appendix 4.A, pp. 4.A.1-54- 4.A.1-64); however, real-time management of south Delta exports and OMR flows will consider HORG operations to minimize effects to listed species, so that modeled increases in entrainment are unlikely to occur. Overall, entrainment-related effects of the CWF H3+ to Longfin Smelt are expected to be similar to or less than the NAA; therefore, the ITP Findings of Fact that the project will not jeopardize the continued existence of Longfin Smelt (Exhibit DWR-1095, p. 386) are consistent with the 2016 FEIR/EIS impact conclusions of not adverse/less than significant.

In summary, by implementing dual conveyance for CWF H3+ operations and considering the above analyses, it is my opinion that there is the potential for Delta Smelt and Longfin Smelt entrainment risk to be reduced from, or at least maintained no more than, the existing levels, which are reasonably protective.

4. THE CWF H3+ NORTH DELTA DIVERSIONS WILL REASONABLY PROTECT DELTA SMELT AND LONGFIN SMELT THROUGH SCREENING AND HABITAT RESTORATION MITIGATING POTENTIAL RESTRICTED ACCESS TO UPSTREAM AREAS

Screening the NDD to Delta Smelt standards (USFWS-recommended criterion of 0.2 feet per second approach velocity), conducting a suite of pre- and post-construction studies to optimize and monitor screen effectiveness, and providing habitat restoration to mitigate for potential reduced access upstream will, in my opinion, reasonably protect Delta Smelt and Longfin Smelt from potential CWF H3+ effects related to the operation of the NDD.

4.A Section 4.A.1.3, p. 4.A.1-9. Modeling is provided in Exhibit DWR-1074, files <CWF_lfs_PTM_results_08262016.xlsx>, <CWF_lfs_PTM_calcs_NAA_08262016.xlsx>, and <CWF_lfs_PTM_calcs_PA_08262016.xlsx>.

[15] A description of the method is provided in the ITP Application (Exhibit DWR-1036) Appendix 4.A, Section 4.A.1.6, p.4.A.1-53. Modeling is provided in Exhibit DWR-1074, file <CWF_longfin_salvage_08172016.xlsx>.

a. Delta Smelt

As described in Mr. Bednarski's testimony (Exhibit DWR-57, p. 9), the capacity of the NDD intakes, their locations, and design were based on recommendations from and consultation with the multiagency Fish Facilities Technical Team. A summary of the process used to identify and refine potential NDD locations is provided in Appendix 3F of the 2016 FEIR/S. (Exhibit SWRCB-102.) As described in the 2016 FEIR/S (Exhibit SWRCB-102, Section 3.3.1.1, p. 3-35), the NDD fish screens would include vertical, structurally reinforced wedge wire screen panels of stainless steel with 1.75-millimeter (0.069-inch) openings, which is the required NMFS standard for waters potentially including salmonid fry less than 60 mm in length. (Exhibit SWRCB-106, p. 578.) As noted in the testimony of Mr. Bednarski (Exhibit DWR-57, p. 10: 6), the NDD would be screened with approach velocity of less than or equal to 0.2 feet per second, which is the USFWS-recommended criterion for Delta Smelt.[16] Per the incidental take limit of the NMFS BO (Exhibit SWRCB-106, Table 2-290, p. 1159), the screen sweeping velocity would be twice the approach velocity. Additional details of the proposed fish screen design are provided in the BA (Exhibit SWRCB-104), Section 3.2.2.2 *Fish Screen Design.*

As noted in Mr. Bednarski's testimony (Exhibit DWR-57, p. 10), each NDD intake would have six separate bay groups. As described in the BA (Exhibit SWRCB-104, p. 3-38), incorporation of 22-foot-wide refugia between bay groups will be evaluated as part of the next engineering design phase of the intakes, because of the length of the screens and potential for extended fish exposure to their influence (screens and cleaners). Design concepts for fish refugia and studies to evaluate their effectiveness are still in development, and final refugia design is subject to review by the fish agencies.

A Fish Facilities Technical Team (FFTT[17]) led by DWR and including NMFS,

---

[16] This is also considered protective of salmonid fry, for which the NMFS criterion is 0.33 feet per second (Exhibit SWRCB-106, Table 2-290, p. 1159).

[17] Also referred to as the NDD Intake Technical Team (NDDTT) in the CDFW ITP (Exhibit SWRCB-107, p. 158).

USFWS, CDFW, and other members is required to be formed under the CWF permit terms (see e.g., Exhibit SWRCB-106 [NMFS BO], p. 1182). The FFTT shall focus on monitoring, design, and operational activities of the NDD, in particular in relation to the various studies that are required to aid in refinement of the fish screen design and to test effectiveness of the screens following construction and operation. These studies include 16 preconstruction studies (Exhibit SWRCB-107, pp. 163 - p.167), of which the most relevant to Delta Smelt are: 1) Site Locations Lab Study (develop physical hydraulic models to optimize hydraulics and sediment transport at each NDD site); 2) Site Locations Mathematical Modeling Study (develop site-specific models to assess the performance of each NDD intake under the full range of tidal and river hydraulic conditions and associated operating conditions); 3) Refugia Lab Study (use laboratory studies to test and optimize fish refugia designs to be incorporated in the final design of the NDD); 4) Refugia Field Study (conduct field experiments to evaluate the effectiveness of incorporating refugia into the NDD intakes to provide areas for juvenile fish to recover from swimming fatigue and avoid exposure to predatory fish); 5) Predator Habitat Locations (perform a field evaluation of predator habitat at similar facilities to inform final design of the NDD intakes); 6) Predator Reduction Methods (evaluate predator reduction techniques implemented at similar facilities to determine whether those techniques could minimize potential predation impacts at the NDD intakes); 7) Flow Profiling Field Study (use field data collection to identify how hydraulics change with flow rate and tidal cycle to inform final screen design and model-based testing of fish screen performance); 8) Deep Water Screens Study (develop a computational fluid dynamics model to evaluate the need for screen hydraulic tuning baffles which can be adjusted in both the vertical and horizontal directions to achieve design requirements to minimize fish impingement and entrainment); 9) Predator Density and Distribution (determine the baseline density, species composition, and seasonal and geographic distribution of predatory fish within the Sacramento River NDD intake reach and in adjacent control reaches, for comparison with test period and full project operations); 11) Baseline Delta Smelt and Longfin Smelt Survey (determine baseline abundance, distribution, and timing of all life stages of Delta Smelt and Longfin Smelt in all portions of the Sacramento River upstream of NDD Intake 5); 14) Delta Smelt Life Cycle Model (develop or enhance mathematical life cycle models to quantitatively assess the effects of abiotic and biotic factors on Delta Smelt and Longfin Smelt, including CWF H3+ effects).

Post-construction NDD studies most relevant to reasonable protection of Delta Smelt include (Exhibit SWRCB-107, pp. 168 - 171): 1) Hydraulic Screen Evaluations to Set Baffles (conduct initial hydraulic field evaluations to measure velocity in front of each screen panel, close to maximum diversion rate, to set initial baffle positions); 2) Long-Term Hydraulic Screen Evaluations (measure approach and sweeping velocity and other hydrodynamics at each intake to allow baffle tuning for compliance with final design criteria); 3) Periodic Visual Inspections (evaluate screen integrity and cleaning mechanism effectiveness in protecting the structural integrity of the screen and maintaining uniform flow distribution through the screen, in order to adjust cleaning intervals to comply with final design criteria); 4) Velocity Measurement Evaluations (determine sweeping velocity along the length of each fish screen and in front of, and within, refugia areas over a range of flow conditions, to determine if final design criteria are being met); 5) Refugia Effectiveness (monitor NDD intake fish screen refugia to evaluate effectiveness in minimizing screen impingement and near-screen predation, at a range of flow conditions, to evaluate compliance with final design criteria); 6) Sediment Management (quantify sediment deposition in front of the screen base, and behind screens, to evaluate the effectiveness of sediment management devices and ensure compliance with final design criteria); 7) Evaluation of Screen Impingement (quantify covered fish species impingement and injury rates, to evaluate performance relative to final design criteria); 8) Screen Entrainment (monitor density of all Covered Fish Species life stages behind fish screens to quantify entrainment rates, to assess performance relative biological and final design criteria); and continuation of preconstruction studies 9, 11, and 14 previously described in my testimony, to assess effects of CWF H3+ during the test period and full operations by comparison with the baseline, preconstruction period.

These required NDD-related studies, particularly in the post-construction phase, will inform adaptive management of the CWF H3+, as described in Dr. Earle's testimony (Exhibit DWR-1014), in order to reasonably protect Delta Smelt.

As described in the 2016 FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2 [Impact AQUA-3], p. 11-3194), the NDD screens are expected to exclude Delta Smelt of approximately 22 mm and larger, and the potential for entrainment of smaller life stages through the screens and impingement on the screens is limited because the NDD are located outside of the main range of Delta Smelt. The FEIR/S concluded that the NDD will be not adverse/less than significant for CWF H3+ entrainment effects. The USFWS BO (Exhibit SWRCB-105, pp. 252- 256) included a quantitative estimate[18] of mortality risk from screen impingement derived from laboratory studies at UC Davis to estimate the potential for mortality across a range of sweeping velocities, in both light (day) and dark (night) conditions; at 0.4 feet per second sweeping velocity[19], the probability of mortality during passage of the proposed fish screens was estimated to be very low (0.11-0.13%) during the day, increasing to around 1.5-2% at night (Figure 9.2.2.2.3-2).

The USFWS BO also analyzed the potential for restricted access to upstream spawning habitat potentially caused by NDD construction removing low-velocity habitat in the left bank of the Sacramento River; such habitat may be used by Delta Smelt to swim upstream (i.e., relatively shallow areas close to the riverbank), rather than the habitat away from shore which may have velocity greater than Delta Smelt's swimming capabilities. A quantitative analysis[20] estimated that the combination of relatively high river velocity, screen length, and potential for injury/mortality will give a low probability (just over 7%) of

[18] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 6.A Section 6.A.2.3, p.6.A-8 to 6.A-10. Modeling is provided in Exhibit DWR-1074, file <North Delta Intakes_ FWS 06012011_v7_CWF_12172015.xls>.

[19] As previously noted, this is the required sweeping velocity at 0.2 feet per second approach velocity, per the terms of the NMFS BO (Exhibit SWRCB-106, p. 1159).

[20] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 6.A Section 6.A.2.3.1.3, p.6.A-10. Modeling is provided in Exhibit DWR-1074, file <NDD fish screen equation checks with worst case punchline_ICF.xlsx>.

passage past each NDD screen, if Delta Smelt occurred along the left bank. (Exhibit SWRCB-105, pp 253-254.) As described on p.174 of the 2017 Certified FEIR (Exhibit SWRCB-108), the CWF H3+ includes approximately 1,750 acres of shallow water habitat mitigation to offset effects related to potential restricted Delta smelt access to upstream spawning habitat. The USFWS BO concluded that implementation of this mitigation will minimize adverse effects to potential passage of Delta Smelt.

b. Longfin Smelt

As noted in AQUA-22 of the 2016 FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2, p. 11-3205), Longfin Smelt entrainment by the NDD would be expected to be extremely low. The species would be expected to occur downstream, and to be rare near the NDD. (see e.g., Exhibit DWR-1036 [ITP Application], Table 4.2-4, p. 4-272.) For the rare individuals occurring near the NDD, the potential effects will be minimized with screen design, as well as habitat restoration, as previously discussed for Delta Smelt. In addition to the pre- and post-construction studies described for Delta Smelt, a Longfin Smelt life cycle model will be developed or enhanced to quantitatively assess the effects of abiotic and biotic factors on Delta Smelt and Longfin Smelt, including CWF H3+ effects. As previously noted in my testimony related to south Delta entrainment (Section III(A)(3)), the ITP Findings of Fact (Exhibit DWR-1095, p. 386) that the project will not jeopardize the continued existence of Longfin Smelt are consistent with the Final EIR/EIS impact conclusions of not adverse/less than significant for entrainment effects.

In light of the NDD being upstream from the main range of Longfin Smelt, screening the NDD to Delta Smelt standards and providing habitat restoration to mitigate for potential reduced access upstream will, in my opinion, reasonably protect Longfin Smelt from potential CWF H3+ effects related to the NDD.

5. CWF H3+ WILL MAINTAIN EXISTING REASONABLE PROTECTION OF DELTA SMELT FALL REARING HABITAT

The CWF H3+ includes the Fall X2[21] criteria from the USFWS 2008 SWP/CVP BO

[21] The location, in kilometers upstream from the Golden Gate Bridge, of near-bottom salinity of 2

and so it is my opinion that the CWF H3+ reasonably protects Delta Smelt fall rearing habitat.

The 2016 FEIR/S (see Exhibit SWRCB-102, Section 11.3.5.2 [Impact AQUA-5], pp. 11-3196 - 11-3198) used an abiotic habitat index[22] developed by Feyrer et al. (2011) to examine the potential differences in fall abiotic habitat between the CWF (H3 and H4 scenarios) and the NAA. The analysis included in the 2016 FEIR/S shows that because both the CWF H3+ and the NAA include the Fall X2 reasonable and prudent alternative from the USFWS 2008 BO, there would be little difference in fall abiotic habitat. (Exhibit SWRCB-102, Section 11.3.5.2, Table 11-4A-3, p. 11-3198.)[23]

The USFWS BO expanded the analysis of rearing habitat to consider late spring and summer months, focusing on the percentage of years from CalSim-II modeling (BA H3+) in which X2 is equal to or greater than 85 km (see Exhibit SWRCB-105, pp. 307-316), indicating that the low salinity zone no longer overlaps Suisun Bay. This analysis found that the frequency of years during the juvenile rearing period for which the low salinity zone would be upstream of Suisun Bay was generally similar in most months, except for August. (Exhibit SWRCB-105, Figure 9.2.3.3.3-9, p. 315.) As noted in the 2017 Certified FEIR (Exhibit SWRCB-108, p. 175), the USFWS BO indicates potential reductions in the extent of low salinity zone rearing habitat in the summer/fall months under the CWF H3+ due to X2 movement upstream. Low salinity zone habitat is believed to provide, along with other factors, suitable rearing conditions for early life stages. However, direct links between the

parts per thousand; the basis for the focus on X2 is provided in the FEIR/S (Exhibit SWRCB-102, Section 11.1.2.2, pp. 11-129 - 11-131).

[22] The abiotic habitat index is the area of habitat weighted by the probability of Delta Smelt occurring in the habitat based on salinity (electrical conductivity) and turbidity (Secchi depth). An overview of the method is provided in the FEIR/S Table 11-16 (Exhibit SWRCB-102, Section, 11.3.2.2, p. 11-232), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.C, Section 5.C.4.5.2 (p.5C.4-117). Modeling is provided in Exhibit DWR-1074, files <X2 Predicted Habitat with Restoration ALT4 2-10-12 TAD.xlsx> and <BDCP_HOS_LOS_X2-DS Abiotic Habitat_update_marin.xlsx>.

[23] A beneficial effect relative to the CEQA baseline ("Existing Conditions") was found because the CEQA baseline did not included the Fall X2 criteria.

extent of low salinity zone habitat/X2 and Delta smelt population responses are unclear and this is an active area of research.[24] The extent and quality of Delta smelt rearing habitat can also be influenced by factors independent of water project operations (e.g., habitat restoration, food web dynamics, and hydrological conditions).

Uncertainty regarding Delta Smelt rearing habitat will be addressed through other regulatory processes, such as the Delta Smelt Resiliency Strategy and re-initiation of consultation on the 2008-09 BOs. In addition, as described in Dr. Earle's testimony (Exhibit DWR-1014), the CWF H3+ includes adaptive management, which commits to further investigations into Delta smelt population dynamics, including identifying factors driving population outcomes. Specific study of Fall X2 (including rearing habitat from July to November) in the context of adaptive management is described in ITP Attachment 5, Appendix 6. (Exhibit SWRCB-107, pp. 60-61.)

Therefore considering that the CWF H3+ includes the Fall X2 criteria from the USFWS 2008 SWP/CVP BO, it is my opinion that the CWF H3+ reasonably protects Delta Smelt fall rearing habitat.

6. CWF H3+ WILL REASONABLY PROTECT LONGFIN SMELT BY IMPLEMENTING SPRING OUTFLOW CRITERIA DEVELOPED IN COORDINATION WITH THE CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE

The CWF H3+ will reasonably protect Longfin Smelt as spring outflows will be consistent with current conditions, based on implementation of criteria developed in coordination CDFW.

As summarized in the 2017 Certified FEIR (Exhibit SWRCB-108, p. 183), the 2016 FEIR/S evaluated potential effects on Longfin Smelt spawning, egg incubation, and rearing habitat by using the Longfin Smelt abundance-X2 regression[25] as an analytical tool (Exhibit

[24] See, for example, discussion provided in FEIR/S (Exhibit SWRCB-102, Section 11.1.2.2, p. 11-131 to 11-132).

[25] An overview of the method is provided in the FEIR/S Table 11-16 (Exhibit SWRCB-102, Section 11.3.2.2, p. 11-231), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.C, Section 5.C.4.5.1 (p.5C.4-117). Modeling is provided in Exhibit DWR-1074, files <BDCP_longfin_smelt_X2_regressions_ESO_11302012.xlsx> and

SWRCB-102, Section 11.3.5.2, pp. 11-3206 to 11-3211). There is a positive correlation between Longfin Smelt abundance (fall midwater trawl index) and average X2 from January through June. The 2016 FEIR/S assumes that the mechanisms underlying this correlation are related to spawning, egg incubation, and rearing habitat. The actual mechanisms underlying the observed correlation are uncertain. (Exhibit SWRCB-102, Sections 11.1.2.2, 11.3.2.2 and 11.3.4.2, pp. 11-130, 11-231, 11-347.) The CWF ITP Application (Exhibit DWR-1036) also uses the Longfin abundance-X2 relationship to assess potential differences in abundance between scenarios.[26]

The CWF H3+ includes spring outflows (March-May) that are consistent with existing outflow conditions, water conveyance/operations, and climate. Therefore, the CWF includes a conservative approach as spring outflows are essentially unchanged as compared to current conditions, not only mitigating potential project-related changes in spring outflow but also climate change. (Exhibit DWR-1095, p. 313.)

The 2016 FEIR/S evaluated Alternative 4A H3 and H4. The 2016 FEIR/S shows a general reduction in predicted Longfin Smelt abundance when comparing H3 to NAA and a general increase in predicted Longfin Smelt abundance when comparing H4 to NAA. (Exhibit SWRCB, Section 11.3.5.2, Table 11-4A-7, p. 11-3209.) These differences arise because of the differences in spring (March-May) Delta outflow (H4 has greater spring outflow than H3). As there is uncertainty of the mechanisms underlying the observed abundance-X2 relationship, spring outflow will be addressed through the adaptive management process. (Exhibit SWRCB-107, Attachment 5, Section 6.2, pp. 28-30; and Attachment 5, Appendix 6, pp. 61-64.) If investigations conducted as part of adaptive management indicate that a change to CWF H3+ spring outflow operations is necessary, Longfin Smelt would remain reasonably protected as the change would reflect agreement

<BDCP_longfin_smelt_X2_regressions_HOS_11302012.xlsx>.

[26] A description of the method is provided in the ITP Application (Exhibit DWR-1036) Appendix 4.A Section 4.A.1, p.4.A.1-2 to p.4.A.1-8). Modeling is provided in Exhibit DWR-1074, file <CWF_LFS_redo_Mount_X2_regressions_ICF_08032016.xlsx>.

by the fishery agencies that the best available science supports the change (see also Dr. Earle's testimony, Exhibit DWR-1014).

Consistent with the FEIR/S conclusion of not adverse/less than significant (Exhibit SWRCB-102, Section 11.3.5.2, pp. 11-3206-11-3211), the CWF ITP Findings of Fact (Exhibit DWR-1095, p. 386) concluded that the CWF H3+ will not jeopardize the continued existence of Longfin Smelt.

It is my opinion that the inclusion of the ITP spring outflow criteria, as developed in coordination with DFW, will reasonably protect Longfin Smelt from the operations of the CWF H3+.

7. OTHER CHANGES IN DELTA HABITAT FROM CWF H3+ OPERATIONS WILL BE LIMITED OR MITIGATED IN ORDER TO REASONABLY PROTECT DELTA SMELT

It is my opinion that changes in Delta habitat from CWF H3+ operations (other than those discussed above related to Delta Smelt rearing habitat) will be limited or will be mitigated in order to reasonably protect Delta Smelt.

a. Water Temperature

As described in Impact AQUA-6 of the 2016 FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2, p. 11-3198), changes in water temperature would be expected to be limited; this is because in-Delta water temperature is primarily affected by atmospheric conditions. (see Exhibit SWRCB-105, p.274.) DSM2-QUAL modeling[27] of the BA H3+ scenario cited by the USFWS BO generally supports this conclusion, with only minor increases in water temperature found. (Exhibit SWRCB-105, p.274 to p.276.)

b. Turbidity

As previously described in my testimony, turbidity is considered an important component of Delta Smelt critical habitat. Impact AQUA-6 of the 2016 FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2, p. 11-3198) found that an average of around 11% of

[27] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.B, Attachment 4. Modeling is provided in Exhibit DWR-1074, file <CWF_DSM2-QUAL_temperature_summary_082015_static.xlsx>.

sediment could be entrained at the NDD, based on the same analysis for the BA H3+ scenario included in the USFWS BO.[28] (Exhibit SWRCB-105, pp.277 – 278.) Reduction in sediment entering the Delta could affect turbidity. The CWF proposes a sediment reintroduction plan to mitigate this potential effect; the ITP (Exhibit SWRCB-107, pp. 46-47 and 162-163) provides further detail on the permitting requirements related to this plan. The 2016 FEIR/S conclusion of not adverse/less than significant (Exhibit SWRCB-102, Section 11.3.5.2, p. 11-3199) is consistent with the USFWS BO (Exhibit SWRCB-105, p. 278), which noted that implementation of the sediment introduction plan will minimize the potential effects of sediment removal.

c. *Microcystis* and Selenium

As noted in the 2017 Certified FEIR (Exhibit SWRCB-108, p.175), the USFWS BO included assessments of potential effects on Delta Smelt from *Microcystis* and selenium. The testimony of Dr. Bryan (Exhibit DWR-81) evaluated the potential for *Microcystis* effects from CWF H3+ operations, which indicated little potential for *Microcystis* increase. With respect to selenium, the USFWS BO (Exhibit SWRCB-105, pp. 285 -286) was consistent with the 2016 FEIR/S in finding little potential for increases in selenium under the BA H3+ scenario that would be of concern to Delta Smelt.[29]

d. Food Web Material Entrainment

The 2017 Certified FEIR (Exhibit SWRCB-108, p. 175) also noted that the USFWS BO assessed the potential for food web material entrainment at NDD, based on the BA H3+ scenario.[30] (Exhibit SWRCB-105, pp. 278-281.) This analysis, focusing on entrainment of

---

[28] A description of the method is provided in the BDCP (Exhibit SWRCB-5) Appendix 5.C Attachment 5C.D, Section 5C.D.3, p.5C.D-13. Modeling is provided in Exhibit DWR-1074, file <NDD_sediment_removal_09172015.xlsx>.

[29] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 6.A, Section 6.A.4.4, p.6.A-40. Modeling is provided in Exhibit DWR-1074, files <Compare2runs_FingerprintingResults_vDH20150619_DV.xlsm>, <Calculation of Se aq conc for CWF NAA PA.xlsx>, and <Se only aq conc for CWF NAA PA_SE Bioaccum calc.xlsx>.

[30] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 6.A, Section 6.A.4.2, p.6.A-34. Modeling is provided in Exhibit DWR-1074, file <CWF_phyto_C_biomass_entrained_pct_08272015.xlsx>.

phytoplankton carbon, suggested little, if any, effects from the CWF H3+, especially when interpreting the modeling results in the context of overall SWP and CVP operations and in situ primary production in the Delta. Decreased south Delta pumping may offset NDD losses or even increase phytoplankton loading as a result of higher contributions from the relatively food web material-rich San Joaquin River.

Considering the factors I have discussed above, it is my opinion that the aforementioned changes in Delta habitat (water temperature, turbidity, *Microcystis*, selenium, and food web materials) caused by CWF H3+ operations will be limited or mitigated and therefore Delta Smelt will be reasonably protected.

B. SALMONIDS AND GREEN STURGEON

As previously noted, my testimony for salmonids and Green Sturgeon first lists my opinions, followed by an overview of the species' biology, and then discusses details supporting my opinions and the reasonable protection of the species during implementation of the CWF H3+:

- Construction effects from CWF H3+ will be avoided, minimized, and mitigated to reasonably protect listed salmonids and Green Sturgeon;
- Implementing dual conveyance under CWF H3+ will maintain or potentially increase existing reasonable protection of listed salmonids and Green Sturgeon from entrainment risk at the south Delta export facilities;
- The CWF H3+ NDD will be screened and operated to meet salmonid protection standards and will be subject to numerous pre- and post-construction studies to provide reasonable protection of listed and salmonids and Green Sturgeon;
- CWF H3+ NDD bypass flow criteria, real-time operational adjustments, and mitigation will reasonably protect juvenile listed salmonids emigrating downstream in the Sacramento River;
- Construction and operation of a Head of Old River Gate will reasonably protect San Joaquin River basin salmonids;
- CWF H3+ operations will limit or mitigate potential changes in habitat suitability to

reasonably protect listed salmonids and Green Sturgeon;

- CWF H3+ avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect unlisted salmonids and Pacific Salmon Essential Fish Habitat.

1. OVERVIEW OF SALMONID AND GREEN STURGEON STATUS AND BIOLOGY

In this testimony, I will provide an overview of salmonid and Green Sturgeon status and biology, with emphasis on in-Delta aspects. Dr. Wilder's testimony (Exhibit DWR-1013) provides background information on upstream life stages of these species. The following summaries are largely based on the FEIR/S (Exhibit SWRCB-102) Appendix 11A, the CWF BA (Exhibit SWRCB-104) Appendix 4.A, and the NMFS BO (Exhibit SWRCB-106) with additional materials as noted.

a. Sacramento River Winter-Run Chinook Salmon

Sacramento River winter-run Chinook Salmon is listed as endangered under ESA and CESA. This species primarily occurs within the Delta and adjacent areas during adult upstream migration (principally December to April) and juvenile emigration/rearing from November/December to April/May. (Exhibit SWRCB-106, Table 2-5, p. 67.) Designated critical habitat in the Delta and adjacent areas includes the water, bottom, and adjacent riparian zones of the mainstem Sacramento River and all waters from Chipps Island westward to Carquinez Bridge. (Exhibit SWRCB-106, Appendix B, Figure B-1, p. 4.) Critical habitat physical or biological features (PBFs) essential for conservation in the Delta and adjacent areas include: access upstream for adults and downstream for juveniles; adequate river flows for downstream juvenile transport; habitat areas and adequate prey (aquatic and terrestrial invertebrates) that are not contaminated; and riparian habitat for successful juvenile development and survival.[31] Major threats and stressors in the Delta and adjacent areas include reduced rearing and outmigration habitat, predation,

[31] A detailed description of the PBFs for NMFS-listed species is provided in the NMFS BO (Exhibit SWRCB-106), Appendix B, sections 1.1.2 (winter-run Chinook Salmon), 1.2.2 (spring-run Chinook Salmon), 1.3.2 (Central Valley steelhead), and 1.4.2 (Green Sturgeon).

entrainment, and exposure to toxins. The estimated number of adult spawners greatly decreased from the 1960s/1970s to 1980s/1990s, with an increase in the early-mid 2000s; since implementation of the 2008-09 BiOps, numbers have fluctuated from less than 1,000 (2011: 827) to over 6,000 (2013: 6,123). (Exhibit SWRCB-106, Appendix B, Figure B-2, p.12.) The number of spawning adults is used to estimate egg production and survival to the Delta is estimated based on environmental conditions. Since 2009, the number of juvenile winter-run Chinook entering the Delta ranged between approximately 125,000 fish in 2014 and 1.2 million fish in 2013. (Exhibit SWRCB-106, Appendix B, Figure B-4, p. 14.)

b. Central Valley Spring-Run Chinook Salmon

Central Valley spring-run Chinook Salmon is listed as threatened under ESA and CESA. Occurrence in the Delta and adjacent areas during adult upstream migration is from January to June, and juvenile emigration/rearing is from November to June, with a peak in young of the year fish in March/April. (Exhibit SWRCB-106, Table 2-6, p. 7.) Designated critical habitat in the Delta and adjacent areas includes the mainstem Sacramento River and a number of sloughs in the northern Delta. Critical habitat needs and threats and stressors in the Delta and adjacent areas are similar to those previously described for winter-run Chinook Salmon. The estimated adult spring-run Chinook Salmon run size has fluctuated widely since the mid-1980s, with the Feather River Hatchery population at times being greater than the number of spawners in tributary populations, including during the recent drought when the number of tributary spawners reached a low of less than 1,200 fish in 2015. Although the main distribution is within the Sacramento River basin, reintroduction of spring-run Chinook Salmon to the San Joaquin River basin has begun, and spring-running Chinook Salmon have been observed in San Joaquin River tributaries.

c. California Central Valley Steelhead

California Central Valley steelhead is listed as threatened under ESA. The main period of adult occurrence in the Delta is during August to October, with a peak in September, and juveniles primarily occur in the Delta during February (hatchery-released fish) and March to May (wild fish). (Exhibit SWRCB-106, Table 2-7, p.74.) Designated critical habitat includes most of the Delta and much of the adjacent areas. (Exhibit SWRCB-106, Appendix B, Figure B-7, p.37.) Critical habitat needs and threats and stressors in the Delta and adjacent areas are similar to those previously described for winter-run Chinook salmon. Population status of steelhead has not been as systematically monitored as Chinook Salmon, but generally numbers are thought to be far fewer than occurred historically, and although recent estimates have fluctuated widely, most fish appear to be of hatchery origin. (e.g., Exhibit SWRCB-106, Appendix B, Figure B-12, p.47.)

d. Central Valley Fall- and Late Fall-run Chinook Salmon

Central Valley fall- and late fall-run Chinook Salmon are considered to be a single evolutionary significant unit (ESU) by NMFS. The ESU is not listed under ESA or CESA, but is a federal Species of Concern and a California Species of Special Concern (SSC). Given the importance of fall-run Chinook Salmon in particular to commercial fisheries, the species' occurrence is an important Magnuson-Stevens Fishery Conservation and Management Act consideration for effects to Essential Fish Habitat (EFH) of Pacific Coast salmon. Occurrence within the Delta and adjacent areas for fall-run Chinook Salmon is primarily July to November for adults and January to June for juveniles (Exhibit SWRCB-102, Appendix 2A, Table 2A.5-1, p.103), and for late fall-run Chinook Salmon is from December/January to March for adults and October/November to May for juveniles. (Exhibit SWRCB-102, Appendix 2A, Table 2A.5-2, p.104.) Estimated fall-run Chinook Salmon adult population abundance is generally one to two orders of magnitude greater than that of late fall-run Chinook Salmon, with the abundance of the overall ESU demonstrating peaks and troughs over the last several decades, including a substantial decline in 2007 to 2009. Fall-run Chinook Salmon spawning in rivers forms the bulk of the ESU, although hatchery fall-run make up an appreciable portion of overall abundance in some years.

e. Southern Distinct Population Segment of North American Green Sturgeon

The Southern DPS of North American Green Sturgeon is listed as threatened under ESA, with designated critical habitat including the legal Delta except for certain areas, as well as adjacent areas upstream and downstream of the Delta. (Exhibit SWRCB-106, Appendix B, Figure B-13, p.55.) Spawning and initial rearing occurs in upstream areas, with juveniles moving downstream to enter the Delta and adjacent areas at about 10 months old (200 millimeters long). Green Sturgeon, particularly juveniles, may occur within the Delta and adjacent areas for all or most of the year. (Exhibit SWRCB-106, Appendix B, Table B-7, p.68.) The PBFs of critical habitat include food resources (primarily mysid shrimp and amphipods), water flow (including sufficient flow for adults to orient upstream), water quality, migratory corridors, water depth, and sediment quality. Threats and stressors in the Delta and adjacent areas include migration barriers (e.g., Fremont Weir), exposure to toxins (e.g., selenium in invasive clams), fishing mortality, reduced rearing habitat, non-native species, dredging, entrainment, and low flows. Population size of Green Sturgeon is not well monitored; the main index of abundance is salvage at the south Delta export facilities, which has shown very few individuals salvaged in recent years compared to the 1980s and 1990s. (Exhibit SWRCB-106, Appendix B, Figure B-14, p.70.)

Other aspects of the biology of salmonids and Green Sturgeon that are relevant to evidence of reasonable protection from potential effects of CWF H3+ are provided as necessary in the following opinions.

2. CONSTRUCTION EFFECTS FROM CWF H3+ WILL BE AVOIDED, MINIMIZED, AND MITIGATED TO REASONABLY PROTECT LISTED SALMONIDS AND GREEN STURGEON

The combination of in-water work windows, environmental commitments, avoidance and minimization measures, conservation measures, and habitat mitigation will reasonably protect listed salmonids and Green Sturgeon from CWF H3+ construction effects.

The general nature of CWF H3+ construction effects on listed salmonids and Green Sturgeon will be similar to the effects previously discussed in my testimony for Delta Smelt and Longfin Smelt (i.e., temporary increases in turbidity, accidental spills, disturbance of contaminated sediments, underwater noise, fish stranding, permanent loss of habitat, and predation); see the FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2), Impact AQUA-37 (winter-run Chinook Salmon: p.11-3214), Impact AQUA-55 (spring-run Chinook Salmon:

p.11-3247), Impact AQUA-91 (steelhead: p.11-3363), and Impact AQUA-127 (Green Sturgeon, p.11-3444). As with the smelts, the primary means to reasonably protect salmonids from potential construction effects is through the implementation of the location-specific summer/early fall in-water work windows. (2017 Certified FEIR, Exhibit SWRCB-108, p. 103.) In addition, barge operations are constrained to specific work windows in order to protect salmonids from potential noise, disturbance, and injury or mortality from barge propellers. (2017 Certified FEIR, Exhibit SWRCB-108, p.104.) As is evident from examination of species timing (e.g., Exhibit SWRCB-106, Tables 2-5, [p.67], 2-6 [p.71], and 2-7 [p.74]) and overlap with construction (Exhibit SWRCB-102, Section 11.3.1.1, Table 11-7, p. 11-203), the in-water work windows and barge operations restrictions largely allow avoidance of in-water effects.

The main potential for overlap with construction of the CWF H3+ is for steelhead adults (see Exhibit SWRCB-106, Table 2-7, p. 74) and Green Sturgeon juveniles (see Exhibit SWRCB-106, Table 2-8, p. 77-78). For these life stages in particular the numerous environmental commitments, avoidance and minimization measures, and conservation measures described in Appendix 3B of the FEIR/S (Exhibit SWRCB-102) will limit potential effects to provide reasonable protection.

Permanent or temporary loss of tidal perennial habitat will occur from constructing CWF H3+ facilities, including 26.7 acres related to the NDD, 2.9 acres at the HORG, and 22.4 acres at the barge landings. In addition, just over 1 mile of channel margin habitat will be lost because of NDD construction. The losses of tidal perennial habitat will be mitigated by a total of 154.8 acres of restoration, and 4.3 miles of channel margin restoration, which, as described in Condition of Approval 10.2 of the CWF ITP (Exhibit SWRCB-107, p. 211), will be implemented on the Sacramento River or associated sloughs downstream of Freeport and prior to initiation of covered activities.

The FEIR/S evaluated similar construction-related impact mechanisms as were included in the NMFS BO, although the latter somewhat adapted or expanded upon particular impacts, such as barge traffic acoustic, sediment, and propeller injury/entrainment effects; reduced prey availability from riverbed disturbances; predation effects from in-water structures; and temperature effects from loss of riparian habitat. However, consistent with the FEIR/S, the NMFS BO also concluded that the construction effects are expected to be avoided, minimized, or mitigated. Thus, the FEIR/S's (Exhibit SWRCB-102, Section 11.3.5.2) conclusions of construction being not adverse/less than significant (winter-run Chinook Salmon: pp. 11-3216 - 11-3217; spring-run Chinook Salmon: pp.11-3247 - 11-3248; steelhead: pp.11-3364 - 11-3365; Green Sturgeon: p.11-3446 - 11-3447) are consistent with the NMFS BO's conclusion (Exhibit SWRCB-106, p. 1111) that the CWF H3+ would not be likely to jeopardize listed salmonids and Green Sturgeon nor would adversely modify their critical habitat.

In my opinion the combination of in-water work windows, avoidance and minimization measures, and habitat mitigation will reasonably protect salmonids and Green Sturgeon from CWF H3+ construction effects.

3. IMPLEMENTING DUAL CONVEYANCE UNDER CWF H3+ WILL MAINTAIN OR INCREASE EXISTING REASONABLE PROTECTION OF LISTED SALMONIDS AND GREEN STURGEON FROM ENTRAINMENT RISK AT THE SOUTH DELTA EXPORT FACILITIES

With the implementation of dual conveyance under the CWF H3+, there will be less use of the south Delta export facilities, and therefore there is the potential for entrainment risk to listed salmonids and Green Sturgeon to be reduced from, or at least maintained no more than, the existing levels, which in my opinion are reasonably protective.

As previously noted in my testimony related to smelts, the 2008-09 BOs have reduced the potential for entrainment loss at the south Delta export facilities since 2008–2009 including listed salmonids and Green Sturgeon. Implementation of dual conveyance under the CWF H3+ has the potential to reduce entrainment risk further because of reduced south Delta exports.

The FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2) illustrated, based on the salvage-density method[32] applied to scenario H3, that with less south Delta exports under

[32] An overview of the method is provided in the FEIR/S Table 11-14 (Exhibit SWRCB-201, Section

CWF H3+ there is the potential for less entrainment loss under CWF H3+ compared to NAA, particularly in wetter years when the NDD would be used more (winter-run Chinook Salmon: Table 11-4A-9, p.11-3218; spring-run Chinook Salmon: Table 11-4A-23, p.11-3249; steelhead: Table 11-4A-73, p.11-3366; Green Sturgeon: Table 11-4A-92, p.11-3448). This, in association with analyses related to NDD impacts (discussed further in my testimony below), formed the basis for the conclusion of entrainment effects being not adverse/less than significant (winter-run Chinook Salmon: p. 11-3219; spring-run Chinook Salmon: p.11-3250; steelhead: p.11-3367; Green Sturgeon: p. 11-3448). (Exhibit SWRCB-102, Section 11.3.5.2)

The NMFS BO also used the salvage-density method[33], applied to the BA H3+scenario, to also show the potential for less entrainment loss under CWF H3+ compared to NAA. (Exhibit SWRCB-106, winter-run Chinook Salmon: Table 2-183, p.696; spring-run Chinook Salmon: Table 2-190, p.707; steelhead: Table 2-196, p.11-3366; Green Sturgeon: Table 2-201,[34] p. 716.) In addition, the NMFS BO used a method specific to hatchery-origin winter-run Chinook Salmon juveniles which includes consideration not only of exports but also of Sacramento River flows as a broader hydrodynamic influence on entrainment risk. (Exhibit SWRCB-106, Section 2.5.1.2.7.3.2.1.3 Juvenile Salvage Estimates Using the Zeug and Cavallo (2014) Method for Hatchery Produced Winter-run Chinook Salmon[35], pp. 699 – 702.) This analysis was consistent with the salvage-density

11.3.2.1, p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.4, p. 5.B-59). Modeling is provided in Exhibit DWR-1074, files in folder <salvage_density_NMFS_FEIRS>.

[33] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.D, Section 5.D.1.1.2.1, p.5.D-2. Modeling is provided in Exhibit DWR-1074, files in folder <salvage_density_NMFS_BA>.

[34]Note that Table 2-201 includes values based on the average of the water-year-type averages presented in the BA (Exhibit SWRCB-104, Table 5.4-24, p. 5-193). This simple averaging does not account for the different number of years in each water-year type.

[35] A description of the method is provided in the BA (Exhibit SWRCB-104, Appendix 5.D, Section 5.D.1.1.2.2, p.5.D-35. Modeling is provided in Exhibit DWR-1074, files <SalvageBootstrapAnnualSummary.xlsx>, <SalvageBootstrapDaily_09252015.xlsx>, and <SalvageMonthlyMedians.csv>.

method in illustrating the potential for entrainment to be less under the CWF H3+ than NAA. (Exhibit SWRCB-106, Figure 2-143 and Table 2-187, p.701 to p.702.) The potential for reduction in south Delta entrainment loss contributed to the overall NMFS BO (Exhibit SWRCB-106, p. 1111) conclusions that the CWF H3+ would not be likely to jeopardize listed salmonids and Green Sturgeon nor would it adversely modify their critical habitat; this is consistent with the FEIR/S conclusions for entrainment impacts.

It is my opinion that with the implementation of dual conveyance under the CWF H3+, in consideration of the analyses discussed above, there is the potential for listed salmonid and Green sturgeon entrainment risk to be reduced from, or at least maintained no more than, the existing levels, which I believe currently provide reasonable protection.

4. THE CWF H3+ NDD WILL BE SCREENED AND OPERATED TO SALMONID PROTECTION STANDARDS AND WILL BE SUBJECT TO NUMEROUS PRE- AND POST-CONSTRUCTION STUDIES TO PROVIDE REASONABLE PROTECTION OF LISTED SALMONIDS AND GREEN STURGEON

Screening the NDD to salmonid protection standards and conducting preconstruction studies to inform final screen design and post-construction studies to assess screen effectiveness will in my opinion provide reasonable protection for listed salmonids and Green Sturgeon.

As described in my earlier testimony regarding potential NDD effects to Delta Smelt, the capacity of the NDD intakes, their locations, and design were based on recommendations from and consultation with the multiagency Fish Facilities Technical Team. Screening the NDD to the 1.75-millimeter screen opening salmonid fry protection standard, in addition to the NDD's 0.2-feet per second approach velocity being appreciably lower than the salmonid fry standard (0.33 feet per second[36]), would reasonably protect juvenile salmonids.

Juvenile listed salmonids and Green Sturgeon encountering the NDD could be subject to entrainment through the screens, impingement on the screens, or predation near

[36] Exhibit SWRCB-106, Table 2-290, p. 1159.

the screens. Screening the NDD to Delta Smelt and salmonid protection standards (see my earlier testimony on Delta Smelt) will provide reasonable protection for listed salmonids and sturgeon because the fish will be large enough to be effectively screened (see discussion in Exhibit SWRCB-102, Section 11.3.5.2, Impacts AQUA-39 [p.11-3218], AQUA-57 [p.11-3249], AQUA-93 [p.11-3366], and AQUA-129 [p.11-3447]), but there is uncertainty in the effects of the screens given their length and the fact that field-based studies have not been undertaken of potential effects. As summarized in the 2017 Certified FEIR (Exhibit SWRCB-108, p. 156), the NMFS BO illustrated the potential for entrainment and impingement effects using injury and mortality rates from various studies both within and outside the Delta, and several assumptions regarding the proportion of juvenile salmonids that could encounter the screens. (Exhibit SWRCB-106, Section 2.5.1.2.5 North Delta Diversion Intake Screen Impingement and Entrainment, beginning at p. 572.) For example, for winter-run Chinook Salmon, NMFS estimated that the probability of neither injury nor mortality occurring could range from 91% (if 50% of the population was exposed to the screens) to over 95% (if 25% of the population was exposed to the screens). (Exhibit SWRCB-106, Tables 2-163 and 2-164, pp .588 – 589.)

As previously described for Delta Smelt, the CWF H3+ includes preconstruction studies to refine NDD facility design in order to minimize impacts to special-status fish species, and monitoring after operations begin to assess screen effectiveness in order to inform the need for subsequent changes to screen design or operation. The pre- and post-construction studies are summarized in my earlier testimony on Delta Smelt and described in the CWF ITP. (Exhibit SWRCB-107, pp. 163-167.) Preconstruction studies that are specific to salmonids include 10) NDD Intake Reach Baseline Juvenile winter-run and spring-run Chinook Salmon Survival Rates (quantify baseline survival rates for listed juvenile Chinook Salmon before initiation of construction activities at the NDD intakes based on empirical field data collection); 12) Through Delta Baseline Juvenile winter-run and spring-run Chinook Salmon Survival Rates (develop a Freeport flow-based index of baseline survival rates for juvenile listed Chinook Salmon to Chipps Island through the full range of inflows and South Delta exports); 13) Monitoring Sacramento River Reverse Flows (monitor the magnitude, frequency, and duration of reverse flows at the Georgiana Slough junction); and 16) winter-run and spring-run Chinook Salmon Life Cycle Models (support and refine existing NMFS life cycle models for winter-run Chinook; verify the models with field data; quantitatively assess abiotic and biotic factors, including CWF H3+ effects; and expand the winter-run model to spring-run Chinook). These studies, as well as the relevant studies described in my earlier testimony for Delta Smelt, will also be undertaken after construction to assess NDD screening effectiveness[37].

As discussed in the NMFS BO (Exhibit SWRCB-106, pp. 577 -578) and CWF ITP (Exhibit SWRCB-107, p. 161), the CWF H3+ will include a phased testing period prior to full operations in order to evaluate NDD performance across a range of pumping rates and flow conditions, with USFWS, NMFS, and DFW being responsible for evaluating and determining whether the NDD are meeting operational and biological criteria[38] and if full operations can commence. The FEIR/S concluded that entrainment effects of the NDD, together with consideration of entrainment effects at the south Delta export facilities and other locations, would not be significant for listed salmonids and Green Sturgeon. (Exhibit SWRCB-102, Section 11.3.5.2, Impacts AQUA-39 [p.11-3219], AQUA-57 [p.11-3250], AQUA-93 [p.11-3367], and AQUA-129 [p.11-3448].) This was consistent with the NMFS BO's overall conclusion of no jeopardy and no adverse modification of critical habitat.

In light of screening the NDD to salmonid protection standards and refining final screen design and operations, as well as monitoring of screen effectiveness, through adaptive management, it is my opinion that the CWF H3+ will reasonably protect juvenile listed salmonids and Green Sturgeon.

---

[37] A full summary of the required post-construction studies is provided in the CWF ITP (Exhibit SWRCB-107, pp. 168-171).

[38] Biological criteria are described on p. 172 of the CWF ITP (Exhibit SWRCB-107); operational criteria are described in Section 9.9 of the CWF ITP (beginning at p. 176).

5. CWF H3+ NDD BYPASS FLOW CRITERIA, REAL-TIME OPERATIONAL ADJUSTMENTS, AND MITIGATION WILL REASONABLY PROTECT JUVENILE LISTED SALMONIDS EMIGRATING DOWNSTREAM IN THE SACRAMENTO RIVER

The inclusion of NDD bypass flow criteria, real-time operational adjustments in response to fish presence, and mitigation (a nonphysical barrier and tidal habitat restoration) will in my opinion reasonably protect juvenile listed salmonids emigrating downstream in the Sacramento River.

As described in the FEIR/S, Delta flows have importance for juvenile salmonids in terms of affecting survival. (see discussion in Exhibit SWRCB-102, Section 11.3.5.2, Impact AQUA-42 for Alternative 1A, winter-run Chinook Salmon, pp. 11-382 - 11-383.) Several approaches were used to assess the potential for effects to migrating juvenile salmonids, including comparison of flows downstream of the NDD (based on CalSim-II modeling), bioenergetics modeling and empirical estimates for predation losses at the NDD[39], and the Delta Passage Model (DPM[40]) for the overall effects of flow and changes in fish routing through the Delta. These analyses are described in the FEIR/S' assessment of impacts to migration conditions. (Exhibit SWRCB-102, Section 11.3.5.2, winter-run Chinook Salmon: Impact AQUA-42, pp: 11-3234 - 11-3243; spring-run Chinook Salmon: Impact AQUA-60, pp. 11-3278 - p.11-3290; steelhead: Impact AQUA-96, pp.11-3397 - 11-3420.) Predation losses at the NDD are particularly uncertain and resulted in a broad range of estimates (e.g., for winter-run Chinook Salmon, between <1% and 12% of the juvenile population). Flow-based effects from the DPM for H3 and H4 suggested that juvenile survival under the CWF H3+ could be less than NAA. (e.g., <1% to 9% lower survival for winter-run Chinook Salmon; Table 11-4A-21 on p. 11-3237 of the Exhibit SWRCB-102, Section 11.3.5.2.) The

---

[39] A summary of the methods is provided in the FEIR/S, Exhibit SWRCB-102, Section 11.3..2.3, pp. 11-244 - 11-245; details are provided in BDCP (Exhibit SWRCB-5) Appendix 5.F, Section 5.F.3.2, p.5.F-14 to p.5.F-22. Modeling is provided in Exhibit DWR-1074, file <July 2012 Salmon Bioenergetics _LLT_0.47x_marin.xlsx>.

[40] A summary of the method is provided in the FEIR/S Table 11-16 (Exhibit SWRCB-102, Section 11.3.2.2, p. 11-230); details are provided in BDCP (Exhibit SWRCB-5) Appendix 5.C, Section 5C.4.3.2.2, p.5C.4-40 to 5.C.4-62. Modeling is provided in Exhibit DWR-1074, files in folder <DPM>.

FEIR/S concluded that given the CWF's inclusion of bypass flow criteria, implementation of real-time operational adjustments for fish presence, and environmental commitments such as the Georgiana Slough nonphysical barrier to reduce the proportion of fish entering the interior Delta where survival is lower, the effects to juvenile salmonids would not be adverse and would be less than significant. As noted in the 2017 Certified FEIR (Exhibit SWRCB-108, p.156), studies in support of adaptive management will be used to better understand baseline conditions near the NDD, along with potential effects at/near the intakes during operations.[41] This information will then be used to further improve understanding of species needs, potential effects from operations, and methods to reduce negative effects.

As summarized in the 2017 Certified FEIR (Exhibit SWRCB-108, p.156 to p.157), the NMFS BO included several additional quantitative analyses based largely on DSM2-HYDRO modeling of BA H3+ to assess potential effects on listed salmonids: a channel velocity/flow routing analysis within the Delta[42]; hydrodynamics/entrainment into Georgiana Slough analysis, analysis of reverse flow conditions at the Sacramento River-Georgiana Slough junction under several NDD operating scenarios, and a travel time analysis (Perry 2016)[43]; and flow-survival analyses based on Newman (2003: spring-run Chinook Salmon only)[44] and Perry et al. (2017).[45] (See Exhibit SWRCB-106, Sections 2.5.1.2.7.1 Travel

---

[41] See the earlier discussion of the pre- and post-construction studies at the NDD in Sections III(A)(4) and III(B)(4) of my testimony.

[42] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.D, Section 5.D.1.2.1, p.5.D-37 to p.5.D-39. Modeling is provided in Exhibit DWR-1074, files in folders <DSM2_HYDRO_NAA> and <DSM2_HYDRO_PA>.

[43] These methods are described in Appendices F and G of the NMFS BO (Exhibit SWRCB-106). The analyses were developed by NMFS and its collaborators, who possess the modeling as part of their administrative record.

[44] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.D, Section 5.D.1.2.3, p.5.D-238 to p.5.D-244. Modeling is provided in Exhibit DWR-1074, file <Newman_2003_calculations_10d_ave_CWF_08242015.xlsx>.

[45] This method is described in Appendix G of the NMFS BO (Exhibit SWRCB-106). The analysis was developed by NMFS and its collaborators, who possess the modeling as part of their

Time, beginning at p. 600, 2.5.1.2.7.2 Outmigration Routing, beginning at p. 652, 2.5.1.2.7.3 South Delta Operations, beginning at p. 682, and 2.5.1.2.7.4 Delta Survival, beginning at p. 727.) In addition, two winter-run Chinook Salmon life-cycle models were applied (Interactive Object-Oriented Simulation [IOS][46] and the Winter-run Chinook Life Cycle Model [WRLCM][47]) (Exhibit SWRCB-106, Section 2.5.1.2.7.5 Life Cycle Modeling, beginning at p. 791). Overall, the CWF NMFS BO indicated that the CWF potentially could reduce through-Delta survival, increase travel times, and increase entry into the central Delta, where survival is lower.

As noted in the 2017 Certified FEIR (Exhibit SWRCB-108, p.156 to p.157), some limitations to the modeling used in the NMFS BO exist, which overestimate the effects of CWF H3+ operations at the NDD (reduced Sacramento River flows leading to reduced survival). For example, the through-Delta migration of juvenile winter-run Chinook Salmon as represented in the WRLCM is largely at night, which coincided with the main period of NDD pumping based on the simplified assumptions used in operations modeling. This results in potentially overestimating CWF H3+ operation impacts because actual NDD pumping levels will vary across the day based on biological and hydrological conditions, and can be adjusted for diurnal/nocturnal differences in migration tendency. The Perry et al. (2017) flow-survival analysis did not weight migration periods by observed distributions of fish entering the Delta and, in common with other methods, was not able to account for real-time operational adjustments in response to fish presence from monitoring, for example. Subsequent model runs for the Perry et al. (2017) flow-survival analysis showed that potential adverse effects could be reduced with revised real-time operations to allow

---

administrative record.

[46] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.D, Section 5.D.3.1, p.5.D-486 to p.5.D-500. Modeling is provided in Exhibit DWR-1074, files <IOS_NAA.xlsx> and <IOS_PA.xlsx>.

[47] This method is described in Appendix G of the NMFS BO (Exhibit SWRCB-106). The analysis was developed by NMFS and its collaborators, who possess the modeling as part of their administrative record.

operations to be adjusted for as many pulses of juvenile salmonids entering the Delta as necessary. (Exhibit SWRCB-106, Appendix E.)

Both the NMFS BO and the CWF ITP have permit terms for through-Delta survival of juvenile listed salmonids. Inclusion of permit terms based on through-Delta survival essentially accounts for all[48] the potential effects of the CWF H3+ on juvenile listed salmonids. The CWF ITP requires survival following commencement of CWF H3+ operations to be compared to pre-operations survival (i.e., a baseline period). The CWF ITP (Exhibit SWRCB-107, p. 172) requires that through-Delta survival must be equal to or greater than baseline, ensuring that the CWF H3+ must be operated to provide reasonable protection for juvenile listed salmonids. In addition to through-Delta survival criteria, there are criteria for the NDD intake operations to be managed at all times to avoid increasing the magnitude, frequency, or duration of flow reversals in the Sacramento River at the Georgiana Slough junction above pre-Project levels. (Exhibit SWRCB-107, p. 187.) As described in the BA's proposed action description (Exhibit SWRCB-104, pp.3-147 - 3-148), it is anticipated that restoration of over 1,800 acres of tidal habitat (as required for Delta Smelt, described previously in my testimony), in addition to existing tidal habitat restoration commitments, will sufficiently address potential undesirable hydrodynamic effects of NDD operations (e.g., reverse flows at the Georgiana Slough junction). In addition, DWR and Reclamation also commit to providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any CWF H3+-related effects on the frequency, duration, and magnitude of reverse flows caused by NDD operations. (Exhibit SWRCB-104, p. 3-148.)

The NMFS BO's conclusion that the CWF H3+ operations would not jeopardize listed salmonids or Green Sturgeon or adversely modify critical habitat is consistent with

[48] For example, although the discussion in this specific opinion is largely on far-field, Delta hydrodynamics-based effects, through-Delta survival criteria in the permit terms would also account for any near-field effects (e.g., entrainment, impingement, and predation at the NDD) or habitat effects (e.g., less availability of riparian and wetland bench rearing habitat, as described in a subsequent opinion of my testimony).

the FEIR/S conclusions of no significant impact/no adverse effect.

In summary, it is my opinion that the CWF H3+ will reasonably protect juvenile listed salmonids emigrating downstream in the Sacramento River through implementation of bypass flow criteria and real-time operational adjustments, a nonphysical barrier at Georgiana Slough, and tidal habitat restoration as necessary[49]. Monitoring of through-Delta and reach-specific survival compliance criteria as well as Georgiana Slough hydrodynamic criteria will ensure this protection is being provided.

6. CONSTRUCTION AND OPERATION OF A HEAD OF OLD RIVER GATE WILL REASONABLY PROTECT SAN JOAQUIN RIVER BASIN SALMONIDS

In my opinion, the construction and operation of a HORG will reasonably protect San Joaquin River basin listed salmonids.

As summarized in the testimony of Mr. Bednarski (Exhibit DWR-57, p.23-24), the CWF H3+ includes construction of a HORG at the divergence of Old River from the San Joaquin River, with the intent of keeping out-migrating juvenile salmonids in the San Joaquin River as well as improving water quality, in particular in the fall in the Stockton Deep Water Ship Channel where low river flow can result in low dissolved oxygen at times when adult Chinook Salmon are migrating upstream. The FEIR/S examined HORG effects mostly in the context of fall-run Chinook Salmon juvenile through-Delta survival, finding the effect not to be adverse. (Exhibit SWRCB-102, Section 11.3.5.2, Impact AQUA-78, p. 11-3349.) HORG effects to spring-run Chinook Salmon from the San Joaquin River basin were not included in the FEIR/S[50], whereas the potential effects of a HORG on steelhead were examined qualitatively to conclude that juvenile migration success would be aided by the

[49] As previously noted in my testimony, it is anticipated that restoration of over 1,800 acres of tidal habitat under CWF, as well as existing tidal habitat restoration commitments, will sufficiently address potential reverse flows at Georgiana Slough; DWR and Reclamation also commit to providing restoration necessary to meet ESA and CESA standards with respect to the frequency of reverse flows.

[50] At the time of initial preparation of the EIR/S, spring-run Chinook Salmon reintroduction to the San Joaquin River basin was not yet underway and so analyses related to that basin were not included.

HORG. (Exhibit SWRCB-102, Section 11.3.5.2, p. 11-3406.) For spring-run Chinook Salmon, the NMFS BO used the SalSim Through-Delta Survival Function[51] of the BA H3+ scenario to show the potential for greater through-Delta survival under the CWF H3+ as a result of more flow remaining in the San Joaquin River (e.g., Exhibit SWRCB-106, Table 2-230, p. 787). The NMFS BO (Exhibit SWRCB-106, p. 788) considered the results for spring-run Chinook Salmon to be generally applicable to San Joaquin River basin steelhead. The NMFS BO also noted the potential for adverse effects from the HORG from provision of in-water structure for predatory fish, which would be expected to affect only a small proportion of the juvenile salmonid populations due to implementation of structure design elements intended to reduce suitable predator areas, as informed by an interagency HORG Technical Team. (Exhibit SWRCB-106, pp. 595 – 598.)

As noted in the FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2, p. 11-3349), there is some uncertainty in beneficial HORG effects based on mixed evidence from various studies and reviews. The effects of reduced south Delta exports and a HORG on through-Delta survival of San Joaquin River basin juvenile salmonids will be subject to study through adaptive management. (Exhibit SWRCB-107, Attachment 5, Appendix 2, p. 52.)

Considering the potential beneficial effects from the HORG and the implementation of design elements intended to reduce suitable predator areas, it is my opinion that construction and operation of the HORG will reasonably protect San Joaquin River basin listed salmonids.

7. CWF H3+ OPERATIONS WILL LIMIT OR MITIGATE POTENTIAL CHANGES IN HABITAT SUITABILITY TO REASONABLY PROTECT LISTED SALMONIDS AND GREEN STURGEON

In my opinion, CWF H3+ operations will reasonably protect listed salmonids and Green Sturgeon by limiting or mitigating changes in habitat suitability within the Delta and

[51] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.E, pp. 5.E-79 - 5.E-82. Modeling is provided in Exhibit DWR-1074, file <SalSim_Delta_survival_SR_SJR_05162016.xlsx>.

adjacent areas.

a. Riparian and Wetland Bench Inundation

Less flow downstream of the NDD has the potential to reduce inundation of riparian and wetland benches in the Sacramento River and adjacent distributaries that form habitat for juvenile salmonids, as assessed in the NMFS BO analysis of effects on critical habitat. (Exhibit SWRCB-106, pp. 872- 874.) This found that an index of habitat suitability[52] incorporating the duration and depth of inundation was less under the BA H3+ scenario than the NAA, particularly in winter and spring of wet and above normal years. (Exhibit SWRCB-106, Table 2-240, p. 874.) In consideration of the reduction in inundation and the length of habitat involved, the CWF H3+ will mitigate this loss by restoring 4.3 miles of channel margin habitat (including channel margin habitat restored for construction impacts). The inclusion of this mitigation contributed to the NMFS BO conclusion (Exhibit SWRCB-106, p. 1111) that the CWF H3+ would not jeopardize listed salmonids and Green Sturgeon or adversely modify their critical habitat.

b. Water Temperature

The NMFS BO did not analyze the effects on water temperature from CWF H3+ operations in the Delta. As previously described in my testimony for smelts, changes in Delta water temperature are primarily caused by atmospheric conditions and are not the result of water operations. (see Exhibit SWRCB-105, p. 274.)

c. Selenium

The FEIR/S concluded that CWF H3+ operational effects of changes in selenium exposure in covered species, including listed salmonids and Green Sturgeon, would be not adverse/less than significant. (Exhibit SWRCB-102, Section 11.3.5.2, Impact AQUA-219, p. 11-3608.) The NMFS BO did not consider operations-related selenium effects to be an issue of concern for analysis.

---

[52] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.E, Section 5.D.1.3.1, pp. 5.D-268 - D-273. Modeling is provided in Exhibit DWR-1074, file <bench_outputs_07172015.xlsx>.

d. Olfactory cues for Salmonid Adult Upstream Migration

Reductions in Sacramento River flow downstream of the NDD would have the potential to reduce olfactory cues for adult salmonid upstream migration, but the FEIR/S found based on DSM2-QUAL fingerprinting modeling[53] of H3 that these changes would be limited and therefore would not be expected to affect migration. (e.g., Exhibit SWRCB-102, Section 11.3.5.2, discussion for winter-run Chinook Salmon, Impact AQUA-42 on p. 11-3238.) This is consistent with the NMFS BO, which did not consider the effect of sufficient importance for analysis.

e. Delta Outflow (Sturgeon Outflow-Abundance Relationship)

The FEIR/FEIS used a positive relationship between Delta outflow during April and May and White Sturgeon year-class strength[54] and specifically exceedances of several Delta outflow thresholds from CalSim-II modeling of H3 and H4, per the recommendations of USFWS 1995; (see Exhibit SWRCB-102, Section 11.3.5.2, p. 11-3488) to evaluate potential effects on Green Sturgeon (and White Sturgeon) migration, although the exact mechanism is unknown. As noted in the FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2, pp. 11-3465-11-3466), there is uncertainty in whether Delta outflow or flow-related changes in upstream areas is the driving hydrological variable for the relationship and whether the relationship as derived for White Sturgeon is applicable as a surrogate for Green Sturgeon; similar year-class strength data do not exist for Green Sturgeon to derive a relationship for this species. The evaluation predicted that year-class strength would be lower than NAA under the CWF's H3 scenario but greater than NAA under the CWF's H4 scenario because of higher spring outflows under H4. As noted in the FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2, p. 11-3467), the scientific uncertainty regarding which mechanisms are

[53] A summary of the method is provided in the FEIR/S Table 11-16 (Exhibit SWRCB-102, Section 11.3.2.2, p. 11-229); details are provided in FEIR (Exhibit SWRCB-102) Appendix 5.A, p.5A-A36. Modeling is provided in Exhibit DWR-1074, file <DSM2_fingerprinting.xlsx>.

[54] Strength meaning the size of the year-class index derived from trawling in the San Francisco Estuary.

responsible for the positive correlation between White Sturgeon year-class strength and river/Delta flow will be addressed through targeted research and monitoring to be conducted in the years leading up to the initiation of NDD operations as described in the adaptive management and monitoring section in the FEIR/S. (Exhibit SWRCB-102,Chapter 3, Description of Alternatives, Section 3.6.4.2.)[55] These investigations will inform decisions regarding Delta outflow within the range of H3/H4 operations such that the effect on Green Sturgeon Delta flow conditions will not be adverse. The lack of difference between the CWF H3+ and the NAA, together with the commitment to adaptive management and further investigation of flow mechanism effects on sturgeon, contributed to the FEIR/S conclusion of not adverse/less than significant for Green Sturgeon migration (Exhibit SWRCB-102, Section 11.3.5.2, Impact AQUA-132, p.11-3469).

The NMFS BO did not include a quantitative analysis of effects of Delta outflow to Green Sturgeon based on relationships between Delta outflow and White Sturgeon year-class strength. Instead, the relationships are only discussed qualitatively in the text (Exhibit SWRCB-106, p. 812), and the summary in Table 2-260 (Exhibit SWRCB-106, p. 1061) notes that effects are uncertain. This conclusion appears to be related to the analysis conducted in the BA, which based on data provided by NMFS found very little difference in White Sturgeon year-class strength between the BA H3+ and NAA scenarios, using regressions based on both April-May and March-July averaging periods. (Exhibit SWRCB-104, pp.5-197- 5-205.)[56] As with the FEIR/S, the BA analysis noted that there is uncertainty whether the relationship is driven by Delta outflow or other hydrological variables, e.g., Delta inflow, as well as uncertainty in whether Green Sturgeon respond in a similar manner to White Sturgeon. This analysis is representative of the final operations permitted by the ITP, with its additional spring outflow criteria. The FEIR/S's conclusion of not adverse/less

[55] See also CWF ITP (Exhibit SWRCB-107) Attachment 5, Appendix 2, p.54.

[56] A description of the method is provided in the BA (Exhibit SWRCB-104) Chapter 5, pp. 5-197 - 5-198. Modeling is provided in Exhibit DWR-1074, file <Green sturgeon YCI for BA-BiOp_ICF_07072015.xlsx>.

than significant for Green Sturgeon migration conditions is thus consistent with the overall NMFS BO conclusion that the CWF H3+ would not jeopardize Green Sturgeon or modify their critical habitat. (Exhibit SWRCB-106, p. 1111.)

The CWF H3+ operations reasonably protect listed salmonids and Green Sturgeon by limiting or otherwise mitigating changes in habitat suitability within the Delta and adjacent areas.

8. CWF H3+ AVOIDANCE AND MINIMIZATION MEASURES, CONSERVATION MEASURES AND RECOMMENDATIONS, AND OPERATIONAL CRITERIA WILL REASONABLY PROTECT UNLISTED SALMONIDS AND PACIFIC SALMON ESSENTIAL FISH HABITAT

The proposed CWF H3+ avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect unlisted salmonids and Pacific salmon Essential Fish Habitat (EFH).

Fall-run and late fall-run Chinook Salmon were included in the FEIR/S as covered BDCP species and in the NMFS BO 1) to inform the prey base effects analysis for Southern Resident Killer Whale, 2) as a surrogate to inform effects on listed salmonids, and 3) to provide a foundation for the analysis of effects on Pacific salmon EFH.

As noted previously in my testimony for listed salmonids with respect to construction effects (see Section III(B)(2)), the in-water work windows, avoidance and minimization measures, and habitat mitigation will reasonably protect unlisted salmonids and Pacific salmon EFH from CWF H3+ construction effects. The FEIR/S conclusions of no adverse effect/less than significant impact from construction on fall-run/late fall-run Chinook Salmon (Exhibit SWRCB-102, Section 11.3.5.2, Impact AQUA-73, p. 11-3292) are consistent with the NMFS BO’s (Exhibit SWRCB-106, p. 1110) conclusion, made with respect to effects on Southern Resident Killer Whales as a result of effects on unlisted Chinook Salmon, that “the relative benefits from the revised PA [Proposed Action] elements and commitments underlying the determinations for ESA-listed Chinook are generally applicable to all Central Valley Chinook salmon populations.”

As with listed salmonids, the FEIR/S illustrated, based on the salvage-density method[57] applied to scenario H3, that with less south Delta exports under CWF H3+ there is the potential for less south Delta entrainment loss under CWF H3+ compared to NAA. (Exhibit SWRCB-102, Section 11.3.5.2, Table 11-4A-50, p. 11-3294.) The NMFS BO found similar trends in south Delta entrainment loss applying this method[58] to the BA H3+ scenario. (Exhibit SWRCB-106, Tables 2-204 and 2-210, pp. 719 and 724.)

The FEIR/S analyzed potential NDD effects on unlisted salmonids with the same methods as for listed salmonids. These included the Delta Passage Model[59], which showed in Impact AQUA-78 that through-Delta survival of migrating juvenile fall-run Chinook Salmon could be lower under CWF H3+ than NAA with the H3 scenario and higher with the H4 scenario, as a result of the latter scenario having increased flow to meet enhanced spring outflow criteria (Exhibit SWRCB-102, Section 11.3.5.2, p.11-3345, Table 11-4A-70), whereas late fall-run Chinook Salmon could have lower survival under CWF H3+. (Exhibit SWRCB-102, Section 11.3.5.2, Table 11-4A-72, p. 11-3347.) The FEIR/S concluded that with consideration of NDD bypass flow criteria, real-time management, and various environmental commitments (channel margin restoration, Georgiana Slough barrier, and predatory fish relocation[60]) the impact for Scenario 4A H3 and H4 would be not adverse/less than significant. The NMFS BO also used the Delta Passage Model[61] applied

---

[57] An overview of the method is provided in the FEIR/S Table 11-14 (Exhibit SWRCB-102, Section 11.3.2.1, p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.4 (p.5.B-59). Modeling is provided in Exhibit DWR-1074, files in folder <salvage_density_NMFS_FEIRS>.

[58] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.D, Section 5.D.1.1.2.1, p.5.D-2. Modeling is provided in Exhibit DWR-1074, files in folder <salvage_density_NMFS_BA>.

[59] A summary of the method is provided in the FEIR/S Table 11-16 (Exhibit SWRCB-102, Section 11.3.2.2, p. 11-230); details are provided in BDCP (Exhibit SWRCB-5) Appendix 5.C, Section 5C.4.3.2.2, p.5C.4-40 to 5.C.4-62. Modeling is provided in Exhibit DWR-1074, files in folder <DPM>.

[60] In addition to several preconstruction and post-construction studies of predatory fish density, habitat, and relocation methods (see Exhibit SWRCB-107, pp. 164 – 165 and 169), predatory fish relocation methods will be investigated as part of adaptive management (Exhibit SWRCB-107, Attachment 5, Appendix 2, p.52 to p.53).

[61] A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.D, Section

to the BA H3+ scenario to show similar patterns as the FEIR/S analysis of the H3 scenario, i.e., similar or lower through-Delta survival under the CWF H3+ than NAA (Exhibit SWRCB-106, Figures 2-148 and 2-149, pp. 740 and 742). For late fall-run Chinook Salmon, the BA H3+ analysis in the NMFS BO may overestimate impacts because modeling assumptions led to more opening of the Delta Cross Channel (an important factor affecting the proportion of fish entering the low-survival interior Delta) than under the NAA during September to November, whereas real-time operations could make the frequency of openings similar between the NAA and CWF H3+. (Exhibit SWRCB-106, p. 741.)

The ultimate conclusion from the NMFS BO was that the unlisted salmonids (a source of Killer Whale prey) would benefit from the proposed action's measures that are focused on minimizing and mitigating adverse effects to listed salmonids (i.e., the measures previously discussed in my testimony related to listed salmonids such as in-water work windows, environmental commitments, avoidance and minimization measures, conservation measures, habitat mitigation, and real-time operational adjustments). In addition, the NMFS EFH analysis found that adverse effects on EFH would be avoided or minimized by implementation of proposed avoidance and minimization measures and conservation measures, and provided several other conservation recommendations (Exhibit SWRCB-106, pp. 1214 - 1216) which will be implemented in the CWF H3+.

In light of the proposed CWF H3+ avoidance and minimization measures, conservation measures and recommendations, and operational criteria included in the CWF H3+, it is my opinion that the CWF H3+ will reasonably protect unlisted salmonids and Pacific salmon EFH.

C. UNLISTED FISHES COVERED BY BDCP AND OTHER AQUATIC SPECIES OF PRIMARY MANAGEMENT CONCERN

The FEIR/S included analysis of potential effects to unlisted fishes proposed for incidental take coverage under Habitat Conservation Plan (HCP) alternatives, i.e., White

---

5.D.1.2.2, p.5.D-205 to p.5.D-238. Modeling is provided in Exhibit DWR-1074, files in folder <DPM_EFH>.

Sturgeon, Sacramento Splittail, and Pacific and River Lamprey, as well as other aquatic species of primary management concern which were assessed to be important native species (Sacramento Tule Perch) or to have economic importance (i.e., Striped Bass, American Shad, Largemouth Bass, Threadfin Shad, and Bay Shrimp). Overviews of the status and biology of these species is presented in the FEIR/S. (Exhibit SWRCB-102, Appendix 11A,Covered Fish Species Descriptions: pp. 11A-143 - 11A-157; and pp. 11A-176 - 11A-200, and Appendix 11B,Non-Covered Fish and Aquatic Species Descriptions: pp. 11B-1 - 11B-9; pp. 11B-11 - 11B-13.)

1. CWF H3+ AVOIDANCE AND MINIMIZATION MEASURES, CONSERVATION MEASURES AND RECOMMENDATIONS, AND OPERATIONAL CRITERIA GENERALLY WILL REASONABLY PROTECT COVERED FISHES AND OTHER AQUATIC SPECIES OF PRIMARY MANAGEMENT CONCERN

In general, avoidance and minimization measures, conservation measures and recommendations, and operational criteria generally will reasonably protect covered fishes and other aquatic species of primary management concern from CWF H3+ effects in the Delta.

The BDCP-covered fishes in my testimony (White Sturgeon, Sacramento Splittail, Pacific and River Lamprey) spawn upstream of the Delta and generally move downstream into the Delta and adjacent areas as larvae or juveniles, as do Striped Bass and American Shad. Other aquatic species of primary management concern are resident within the Delta (Largemouth Bass, Sacramento Tule Perch, and Threadfin Shad), whereas Bay Shrimp occurs downstream of the Delta.

Although some of the unlisted covered fish and other aquatic species of primary management concern will have more potential for overlap in their occurrence and the timing of CWF H3+ construction activities than listed fish, the avoidance and minimization measures and conservation measures previously described for listed fish, unlisted salmonids, and Pacific Salmon EFH also will reasonably protect these species from construction activities. (Exhibit SWRCB-102, Section 11.3.5.2, White Sturgeon: Impact AQUA-145, p. 11-3472; Sacramento Splittail: Impact AQUA-109, p. 11-3423; Pacific

Lamprey: Impact AQUA-163, p. 11-3494; River Lamprey: Impact AQUA-181, p .11-3516; Non-Covered Aquatic Species of Primary Management Concern: Impact AQUA-199, p. 11-3535.) Likewise, operational effects generally will be limited by screening of the NDD and reductions in south Delta exports, with associated reduction in entrainment.[62] (Exhibit SWRCB-102, Section 11.3.5.2, White Sturgeon: Impact AQUA-147, p. 11-3474; Sacramento Splittail: Impact AQUA-111, p. 11-3425; Pacific Lamprey: Impact AQUA-165, p. 11-3496; River Lamprey: Impact AQUA-183, p. 11-3517.)

Several non-covered aquatic species of primary management concern have statistical relationships[63] between X2 and abundance or survival that were assessed for the FEIR/S to compare CWF scenarios H3 and H4 for Alternative 4A to the NAA. The relative differences between the NAA and the CWF scenarios were relatively small and so the impacts were concluded to be less than significant[64]. (Exhibit SWRCB-102, Section 11.3.5.2, Striped Bass: Tables 11-1A-104, 11-1A-105, 11-1A-106, 11-1A-107, and 11-1A-108, pp. 11-715 - 11-723; American Shad: Tables 11-1A-109 and 11-1A-110, p. 11-727 and p.11-729; Bay Shrimp: Table 11-1A-115, p. 11-749.)

Entrainment of Striped Bass and American Shad early life stages (eggs and larvae) was found to be a significant and unavoidable impact in the FEIR/S. Striped Bass spawn in and upstream of the Delta. Eggs and larvae move downstream at small sizes that could

---

[62] Based on the salvage-density method. An overview of the method is provided in the FEIR/S Table 11-14 (Exhibit SWRCB-102, Section 11.3.2.1, p.11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.4 (p.5.B-59 to p.5.B-67). Modeling is provided in Exhibit DWR-1074, files in folder <salvage_density_FEIRS_unlisted>.

[63] The methods are outlined in the FEIR/S, Exhibit SWRCB-102, Section 11.3.4.2, p. 11-714, with regression coefficients provided by Kimmerer et al. (2009; Exhibit DWR-1091). Modeling is provided in Exhibit DWR-1074, files <BDCP_EIR_EIS_X2_regressions_ALT4_H3_03232015.xlsx> and <BDCP_EIR_EIS_X2_regressions_ALT4_H4_03232015.xlsx>.

[64] There is some uncertainty related to the mechanisms involved in these X2-abundance relationships. As described in the FEIR/S (Exhibit SWRCB-102, Section 11.3.4.2, p. 11-714), Kimmerer et al. (2009) found that for Striped Bass and American Shad greater outflow increasing the quantity of rearing habitat was consistent with observed results, whereas for Bay Shrimp, other mechanisms such as increased residual circulation giving increased transport to rearing grounds was an alternative possibility.

make them susceptible to entrainment at the NDD. The FEIR/S (Exhibit SWRCB-102, Section 11.3.5.2, Impact AQUA-201, p. 11-3537) found that the entrainment of Striped Bass at the NDD would constitute a significant and unavoidable impact of the CWF H3+, based primarily on assessment of ten spring (March, April, May, or June) simulated monthly periods of DSM2 particle tracking[65] modeling results for the H3 operational scenario. (Exhibit SWRCB-102, Section 11.3.4.2, Table 11-1A-96, p. 11-679.) Use of the H3 scenario is conservative, because NDD exports would be less under the CWF H3+ operations because of the Longfin Smelt Delta outflow criteria. Also conservative is the averaging that was undertaken in the FEIR/S, which did not take into account that most Striped Bass spawning occurs from early-mid May to early-mid June. This is shown by particle tracking modeling results from the BA H3+ for Delta Smelt, which for particles released at Sacramento[66] shows entrainment under the CWF H3+ in April and May is considerably less than under the CWF H3+ in March and June. (Exhibit DWR-1092.) These reductions are the result of export constraints from the Longfin Smelt outflow criteria, which are included in CWF H3+. Given that most Striped Bass spawning occurs in the period between May 10 and June 12 (Turner 1976, p.116, Exhibit DWR-1093), this will provide additional protection to Striped Bass early life stages than was indicated in the FEIR/S analysis of H3. A similar situation of Longfin Smelt outflow requirements under H3+ offering additional protection than indicated by the FEIR/S analysis of H3 exists for American Shad early life stages moving downstream, and a greater proportion of the population rears in the Sacramento River and its tributaries upstream of the Delta (Stevens et al. 1987, p.69,

---

[65] The method is described in the FEIR/S (Exhibit SWRCB-102) Appendix 5A, Section A.6, p.5A-A51. Modeling is provided in Exhibit DWR-1074, files in folder <PTM_unlisted>.

[66] I consider particles released at Sacramento to be representative of Striped Bass eggs moving downstream from Sacramento River spawning areas into the Delta. The entrainment method (as originally applied for analysis of Delta Smelt entrainment, considering all particle release locations) is described in the BA (Exhibit SWRCB-104) Appendix 5.B, Section 5.B.3.3, p. 5.B-15; only entrainment at the north Delta intakes, south Delta export facilities, and North Bay Aqueduct was considered in this analysis. Modeling is provided in Exhibit DWR-1074, files <CWF_delta_smelt_PTM_NAA_07212015.xlsx> and <CWF_delta_smelt_PTM_PA_07212015.xlsx>.

Exhibit DWR-1094) than Striped Bass. This will make American Shad less susceptible to NDD entrainment overall than Striped Bass, and there will be more protection from CWF H3+ than was indicated from modeling of H3 in the FEIR/S.

In consideration of the above information, it is my opinion that in general, the CWF H3+ avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect covered fishes and other aquatic species of primary management concern from CWF H3+ effects in the Delta.

D. BIOLOGICAL MODELING METHODS OVERVIEW

This final part of my testimony briefly provides an overview of the biological model methods referenced in my testimony. Additional detail on these models is provided in the sources referenced in my testimony (see below and footnotes in the preceding testimony). In general, the biological models use as their inputs the outputs from the water operations and physical models described in Mr. Reyes' testimony (Exhibit DWR-1016), in particular CalSim-II and DSM2. The sections below are organized similarly to my testimony, first by species and then by the various opinions that I provided to support my evidence of CWF H3+ reasonable protection.

1. Delta Smelt and Longfin Smelt

a. Implementing dual conveyance under CWF H3+ will maintain or potentially increase existing reasonable protection of Delta Smelt and Longfin Smelt from entrainment risk at the south Delta export facilities

i. **Old and Middle River Flow Regressions (Delta Smelt entrainment):** The method assessed south Delta entrainment risk and used two regression equations based on historic data from the south Delta export facilities, one predicting the annual proportion of Delta Smelt adults that are entrained as a function of average December-March Old and Middle River flows, the other predicting the proportion of Delta Smelt larvae/early juveniles that are entrained as a function of average March-June Old and Middle River flows and X2. Old and Middle River flow and X2 data from CalSim-II were used to compare the CWF H3+ and NAA scenarios using these regressions. An overview of the method is provided in the FEIR/S Table 11-14 (Exhibit SWRCB-102, Section 11.3.2.1, p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5, Appendix 5.B, Section 5.B.5.5 (p.5.B-67). Modeling is provided in Exhibit DWR-1074, file <FWS_prop_entrainment_regressions_ESO_HOS_LOS.xlsx>.

ii. **DSM2-PTM (Longfin Smelt entrainment):** This method assessed larval Longfin Smelt entrainment risk based on particle tracking modeling. Particles were assigned starting locations (representative of hatching locations) based on historic observations from the Delta, with the percentage entrained over time (30-60 days) being recorded. The method was used in the FEIR/S (an overview is provided in the FEIR/S Table 11-14 (Exhibit SWRCB-102, Section 11.3.2.1, p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.5 (p.5.B-79); modeling is provided in Exhibit DWR-1074, files < Longfin_Smelt_60d_PTM_results_collated_Marin.xlsx> and < LS PTM Results_60D_NewHydro_ESO(Alt4)_081712_ss_mk_ros

_082012ss_mk.xlsx>) and the ITP application (Exhibit DWR-1036 (a description is provided in the ITP Application Appendix 4.A Section 4.A.1.3, p.4.A.1-9); modeling is provided in Exhibit DWR-1074, files <CWF_lfs_PTM_results_08262016.xlsx>, <CWF_lfs_PTM_calcs_NAA_08262016.xlsx>, and <CWF_lfs_PTM_calcs_PA_08262016.xlsx>).

iii. **Salvage-Density Method (Longfin Smelt entrainment):** This method assessed south Delta entrainment risk for adult and juvenile Longfin Smelt based on historic observations of salvage density (number of Longfin Smelt salvaged per volume of water exported, by month). The historic salvage density was multiplied by CalSim-II modeled exports to compare potential entrainment risk under the CWF H3+ and NAA scenarios. An overview of the method is provided in the FEIR/S (Exhibit SWRCB-102, Section 11.3.2.1) Table 11-14 (p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.4 (p. 5.B-59). Modeling is provided in Exhibit DWR-1074, files <Salvage_Longfin smelt 07072011.xlsm> and <Salvage_Longfin Smelt_WY07132011.xlsm>.

iv. **Salvage-Old and Middle River flow regression (Longfin Smelt entrainment):** This method assessed south Delta entrainment risk (juvenile Longfin Smelt salvage) as a function of average April-May Old and Middle River flows, using a regression equation based on historic data. The regression equation is applied to

CalSim-II data to compare the CWF H3+ and NAA scenarios. A description of the method is provided in the ITP Application (Exhibit DWR-1036) Appendix 4.A, Section 4.A.1.6, p.4.A.1-53. Modeling is provided in Exhibit DWR-1074, file <CWF_longfin_salvage_08172016.xlsx>.

b. The CWF H3+ North Delta Diversions will reasonably protect Delta Smelt and Longfin Smelt through screening and habitat restoration for potential restricted access to upstream areas

i. **Delta Smelt NDD Screen Contact Mortality:** This method used regression equations developed from laboratory research at UC Davis to estimate the percentage of Delta Smelt that could die if making contact with the NDD screens, as a function of approach velocity, sweeping velocity, day/night, and water temperature. Representative values of these variables were used based on design criteria and typical temperatures. A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 6.A Section 6.A.2.3, p.6.A-8 to 6.A-10. Modeling is provided in Exhibit DWR-1074, file <North Delta Intakes_ FWS 06012011_v7_CWF_12172015.xls>.

ii. **Delta Smelt NDD Screen Passage and Survival:** This method assessed the probability of Delta Smelt passing the NDD if occurring immediately adjacent to the screens where relatively high velocity will occur, by applying some of the same equations used in the Screen Contact Mortality method as well as observed river flow data from the Sacramento River at Freeport. A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 6.A Section 6.A.2.3.1.3, p.6.A-10. Modeling is provided in Exhibit DWR-1074, file <NDD fish screen equation checks with worst case punchline_ICF.xlsx>.

c. CWF H3+ will maintain existing reasonable protection of Delta Smelt fall rearing habitat

i. **Delta Smelt Fall Abiotic Habitat Index:** This analysis estimated the extent of Delta Smelt low salinity habitat as a function of X2, an indicator of Delta outflow. The method used a relationship based on historic data between abiotic habitat index (area of habitat weighted by the probability of Delta Smelt occurring in the habitat based on electrical conductivity and Secchi depth as a function of average fall (September-December) X2. This relationship was applied to X2 from CalSim-II modeling to compare CWF H3+ and NAA scenarios. An overview of the method is provided in the FEIR/S Table 11-16 (Exhibit SWRCB-102, Section 11.3.2.2, p. 11-232), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.C, Section 5.C.4.5.2 (p.5C.4-117). Modeling is provided in Exhibit DWR-1074, files <X2 Predicted Habitat with Restoration ALT4 2-10-12 TAD.xlsx> and <BDCP_HOS_LOS_X2-DS Abiotic Habitat_update_marin.xlsx>.

d. CWF H3+ will reasonably protect Longfin Smelt by implementing spring outflow criteria developed in coordination with the California Department of Fish and Wildlife

i. **Longfin Smelt X2-Abundance Regression:** This analysis estimated changes in Longfin Smelt abundance as a function of X2, an indicator of Delta outflow. The method used a published relationship based on historic data between annual abundance indices of Longfin Smelt and average January-June X2. This relationship was applied to X2 from CalSim-II modeling to compare CWF H3+ and NAA scenarios. An overview of the method is provided in the FEIR/S Table 11-16 16 (Exhibit SWRCB-102, Section 11.3.2.2, p. 11-231), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.C, Section 5.C.4.5.1 (p.5C.4-117). Modeling is provided in Exhibit DWR-1074, files <BDCP_longfin_smelt_X2_regressions_ESO_11302012.xlsx> and <BDCP_longfin_smelt_X2_regressions_HOS_11302012.xlsx>.

e. Other changes in Delta habitat from CWF H3+ operations will be limited or mitigated in order to reasonably protect Delta Smelt

i. **DSM2-QUAL Temperature Modeling:** The DSM2-QUAL model was used to model temperature at several locations in the Delta to assess differences between NAA and CWF H3+ scenarios for evidence of potential negative effects on Delta Smelt. A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.B, Attachment 4. Modeling is provided in Exhibit DWR-1074, file <CWF_DSM2-QUAL_temperature_summary_082015_static.xlsx>.

ii. **NDD Sediment Removal:** Estimates of sediment removed by the NDD were obtained by multiplying historic estimates of suspended sediment concentration in the Sacramento River by CalSim-II modeled NDD diversion flows. A description of the method is provided in the BDCP (Exhibit SWRCB-5) Appendix 5.C Attachment 5C.D, Section 5C.D.3, p.5C.D-13. Modeling is provided in Exhibit DWR-1074, file <NDD_sediment_removal_09172015.xlsx>.

iii. **Selenium:** This analysis assessed the risk of excessive selenium accumulation in Delta Smelt under changed Delta water operations from the CWF H3+. Literature-derived estimates of selenium concentration in water flowing into the Delta from different sources (e.g., the San Joaquin River and the Sacramento River) were matched with DSM2-QUAL fingerprinting monthly estimates of the contribution of the different source waters to the water occurring at various locations in the Delta, to give selenium concentrations at each location for the NAA and CWF scenarios. Selenium accumulation in Delta Smelt as a function of selenium water concentration was calculated from published relationships, and assessed relative to a toxicity threshold derived for a Delta fish species (Sacramento Splittail). A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 6.A, Section 6.A.4.4, p.6.A-40. Modeling is provided in Exhibit DWR-1074, files <Compare2runs_FingerprintingResults_vDH20150619_D

V.xlsm>, <Calculation of Se aq conc for CWF NAA PA.xlsx>, and <Se only aq conc for CWF NAA PA_SE Bioaccum calc.xlsx>.

iv. **Food Web Material Entrainment at NDD:** This analysis estimated the percentage of Delta Smelt food web materials (phytoplankton carbon, food for Delta Smelt prey) entrained at the NDD. Historic data for chlorophyll a concentration in the Sacramento River at Hood were converted to phytoplankton carbon concentration estimates using a literature-derived conversion. Potential daily phytoplankton carbon biomass load entrained by the NDD was estimated by multiplying the range of observed phytoplankton carbon concentrations by DSM2-HYDRO modeled NDD diversions. The phytoplankton carbon biomass stock in the Delta was estimated from the phytoplankton carbon concentration at Antioch, multiplied by the volume of the Delta; this allowed the percentage of the total stock entrained by the NDD to be estimated. A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 6.A, Section 6.A.4.2, p.6.A-34. Modeling is provided in Exhibit DWR-1074, files <CWF_phyto_C_biomass_entrained_pct_08272015.xlsx> and <CWF_phyto_C_load_entrained_08262015.xlsx>.

2. Salmonids and Green Sturgeon

a. Implementing dual conveyance under CWF H3+ will maintain or potentially increase existing reasonable protection of listed salmonids and Green Sturgeon from entrainment risk at the south Delta export facilities

i. **Salvage-Density Method (entrainment):** This method assessed south Delta entrainment risk for juvenile salmonids and Green Sturgeon based on historic observations of salvage density (number of fish salvaged per volume of water exported, by month). The historic salvage density was multiplied by CalSim-II modeled exports to compare potential entrainment risk under the CWF H3+ and NAA scenarios. The method was used in the FEIR/S (an overview of the method is provided in the FEIR/S Table 11-14 (Exhibit SWRCB-102, Section 11.3.2.1, p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.4, p.5.B-59; modeling is provided in Exhibit DWR-1074, files in folder <salvage_density_NMFS_FEIRS>) and the BA (a description is provided in the BA Appendix 5.D, Section 5.D.1.1.2.1, p.5.D-2; modeling is provided in Exhibit DWR-1074, files in folder <salvage_density_NMFS_BA>).

ii. **Winter-Run Chinook Salmon Salvage Based on Zeug and Cavallo (2014):** This method assessed south Delta entrainment risk (represented by salvage) of juvenile winter-run Chinook Salmon as a function of Sacramento River flow and south Delta exports, based on a published method. Salvage for the NAA and CWF H3+ scenarios was compared using 7-day-averaged outputs from DSM2-HYDRO modeling as inputs for the estimation function. A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.D, Section

5.D.1.1.2.2, p.5.D-35. Modeling is provided in Exhibit DWR-1074, files <SalvageBootstrapAnnualSummary.xlsx>, <SalvageBootstrapDaily_09252015.xlsx>, and <SalvageMonthlyMedians.csv>.

b. CWF H3+ North Delta Diversion bypass flow criteria, real-time operational adjustments, and mitigation will reasonably protect juvenile listed salmonids emigrating downstream in the Sacramento River

i. **Striped Bass Bioenergetics Model of Preation at the NDD:** This model estimates potential Striped Bass predation of juvenile Chinook Salmon at the NDD. Estimates of the number of Striped Bass that could occur along the NDD fish screens were obtained a large screen in the upper Sacramento River. Daily energy requirements of Striped Bass for metabolism and growth, accounting for predator size and water temperature (from DSM2-QUAL modeling), were used to estimate demand for prey, with Striped Bass predation estimates of Chinook Salmon prey accounting for prey density in the environment and prey size. A summary of the method (and associated fixed-loss predation estimates) is provided in the FEIR/S (Exhibit SWRCB-102, Section 11.3.2.3, pp. 11-244 - 11-245; details are provided in BDCP (Exhibit SWRCB-5) Appendix 5.F, Section 5.F.3.2, p.5.F-14 to p.5.F-22. Modeling is provided in Exhibit Exhibit DWR-1074, file <July 2012 Salmon Bioenergetics _LLT_0.47x_marin.xlsx>.

ii. **Delta Passage Model:** This model estimates juvenile Chinook Salmon survival through the Delta, by simulating entry and movement of the fish in the Delta day by day and estimating survival based on flow-survival relationships and migration pathways derived from tagging studies. Model inputs are from DSM2-HYDRO and daily-downscaled CalSim-II. A summary of the method is provided in the FEIR/S (Exhibit SWRCB-102, Section 11.3.2.2) Table 11-16 (p.11-230); details are provided in BDCP (Exhibit SWRCB-5) Appendix 5.C, Section 5C.4.3.2.2, p.5C.4-40 to 5.C.4-62. Modeling is provided in Exhibit DWR-1074, files in folder <DPM>.

iii. **DSM2-HYDRO Hydrodynamics Assessment:** This method assesses hydrodynamic factors of important to juvenile salmonid survival in the Delta: water velocity (magnitude and daily proportion of time velocity is negative), which influences travel time and risk of predation, and flow routing at channel junctions, which influences whether or not fish enter more dangerous migration pathways such as the interior Delta. These factors were based on DSM2-HYDRO modeling of the CWF H3+ and NAA scenarios. A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.D, Section 5.D.1.2.1, p.5.D-37 to p.5.D-39. Modeling is provided in Exhibit DWR-1074, files in folders <DSM2_HYDRO_NAA> and <DSM2_HYDRO_PA>.

iv. **Hydrodynamics/entrainment into Georgiana Slough, reverse flow conditions at the Sacramento River-Georgiana Slough junction, and through-Delta travel time:** As with the DSM2-HYDRO hydrodynamics assessment, these methods assessed hydrodynamic factors of importance to juvenile Chinook Salmon survival, but included relationships of these factors to fish behavior developed from studies of acoustically tagged fish. Travel time and entrainment probability into Georgiana Slough were compared for the CWF H3+ and NAA scenarios by applying the relationships to modeled daily-downscaled CalSim-II or 15-minute DSM2-HYDRO data. In addition, the probability of flow reversal at the Georgiana Slough junction (an indicator of entrainment risk into the low survival interior Delta) based on Sacramento River flow downstream of the NDD was assessed from an empirically-derived relationship; the effects of various NDD bypass flow criteria were then examined. These methods are described in Appendices F and G of the NMFS BO (Exhibit SWRCB-106). The analyses were developed by NMFS and its collaborators, who possess the modeling as part of their administrative record.

v. **Through-Delta Survival based on Newman (2003):** This method estimated through-Delta survival of juvenile spring-run Chinook Salmon entering the Delta in the Sacramento River, based on published relationships between survival of tagged fish and a number of environmental variables including river flow, south Delta exports, water temperature, Delta Cross Channel gate position, and others. Ten-day average DSM2-HYDRO and DSM2-QUAL modeling outputs provided the inputs for this method, to compare the CWF H3+ and NAA scenarios. A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.D, Section 5.D.1.2.3, p.5.D-238 to p.5.D-244. Modeling is provided in Exhibit DWR-1074, file <Newman_2003_calculations_10d_ave_CWF_08242015.xlsx>.

vi. **Through-Delta Survival (Perry et al. 2017):** This method estimated through-Delta survival of juvenile Chinook Salmon as a function of Sacramento River flow downstream of the NDD. The flow-survival relationships were based on results from acoustically tagged fish, and were specific to different channels in the Delta. Fish were simulated to enter the Delta, and travel time and entry into different channels was based on the relationships previously outlined above. Model inputs were from daily-downscaled CalSim-II modeling outputs. This method is described in Appendix G of the NMFS BO (Exhibit SWRCB-106). The analysis was developed by NMFS and its collaborators, who possess the modeling as part of their administrative record.

vii. **Interactive Object-Oriented Simulation (IOS; winter-run Chinook Salmon life cycle model):** This method is a full life cycle model of winter-run Chinook salmon, which includes the Delta Passage Model (as previously described), as well as upstream (spawning, early development, and fry rearing) and ocean (natural mortality and harvest) survival elements. Upstream survival is based on empirical relationships applied to Sacramento River Water Quality Model (SRWQM) temperature modeling. The model outputs estimates of winter-run Chinook Salmon escapement (number of adults), as well as survival of eggs, fry, and through the Delta, which were compared for the CWF H3+ and NAA scenarios. A description of the method is provided in the BA (Exhibit SWRCB-104) Appendix 5.D, Section 5.D.3.1, p.5.D-486 to p.5.D-500. Modeling is provided in Exhibit DWR-1074, files <IOS_NAA.xlsx> and <IOS_PA.xlsx>.

viii. **NMFS Winter-Run Chinook Salmon Life Cycle Model (WRLCM):** The WRLCM is a full life cycle model that includes many components in order to account for spawning, rearing, and migration in upstream (Sacramento River and floodplains), Delta, and estuarine habitats, as well as ocean survival. The model uses CalSim-II; DSM2-HYDRO and DSM2-QUAL; and SRWQM output to run several submodels (Exhibit SWRCB-106, Appendix H, Figure 3) that provide the inputs that are fed into the WRLCM. The WRLCM provides a number of outputs, among the most of which are number of adult winter-run Chinook Salmon and cohort replacement rate (the number of adults in one year divided by the number of adults three years earlier, to assess if each generation is replacing itself). These and other outputs were compared for the CWF H3+ and NAA scenarios. This method is described in Appendix G of the NMFS BO. (Exhibit SWRCB-106.) The analysis was developed by NMFS and its collaborators, who possess the modeling as part of their administrative record.

c. Construction and operation of the HORG will reasonably protect San Joaquin River basin salmonids

i. **SalSim Through-Delta Survival Function (San Joaquin River basin juvenile Chinook Salmon):** This method estimated through-Delta survival of juvenile Chinook Salmon entering the Delta from the San Joaquin River. The model consisted of an equation based on the Delta survival function from the SalSim life cycle model, which estimates survival based on a statistical relationship to San Joaquin River flow entering the Stockton Deepwater Ship Channel, San Joaquin River temperature at Mossdale, and Striped Bass abundance (which was assumed to be constant for modeling purposes). Modeling inputs to apply the function to compare the CWF H3+ and NAA scenarios were from DSM2-HYDRO (flow) and DSM2-QUAL (temperature). A description of the method is provided in the BA (Exhibit SWRCB-104,Appendix 5.E, p.5.E-79 to p.5.E-82. Modeling is provided in Exhibit DWR-1074, file <SalSim_Delta_survival_SR_SJR_05162016.xlsx>.)

d. CWF H3+ operations will limit or mitigate potential changes in habitat suitability to reasonably protect listed salmonids and Green Sturgeon

i. **Riparian and Wetland Bench Inundation (DSM2-HYDRO):** This method assessed the availability of riparian and wetland bench (shallow-sloped, restored river bank) Chinook Salmon rearing habitat in relation to river stage (water level). A published relationship of habitat suitability for juvenile Chinook Salmon as a function of water depth was applied to water depth on the benches, based on DSM2-HYDRO 15-minute stage data and bench elevation data. These calculations allowed seasonal comparisons of the CWF H3+ and NAA scenarios. A description of the method is provided in the BA. (Exhibit SWRCB-104 Appendix 5.E, Section 5.D.1.3.1, p.5.D-268 to p.5.D-273.) Modeling is provided in Exhibit DWR-1074, file <bench_outputs_07172015.xlsx>.

ii. **Olfactory Cues for Upstream Migration (DSM2-QUAL Fingerprinting):** This analysis assessed potential changes in olfactory cues for upstream migration of adult salmonids by assessing the percentage of water in the western Delta made up by the Sacramento River, San Joaquin River, or other sources. A summary of the method is provided in the FEIR/S Table 11-16 (Exhibit SWRCB-102, Section 11.3.2.2, p. 11-229); details are provided in FEIR (Exhibit SWRCB-102, Appendix 5.A, p.5A-A36. Modeling is provided in Exhibit DWR-1074, file <DSM2_fingerprinting.xlsx>.

iii. **Sturgeon Delta Outflow-Abundance Regressions:** This analysis estimated changes in juvenile White Sturgeon abundance (as a proxy for Green Sturgeon) as a function of Delta outflow. The method was based on historic data linking annual year class indices of these species and average Delta outflow during the early life stages (April-May and March-July). This relationship was applied to Delta outflow from CalSim-II modeling to compare CWF H3+ and NAA scenarios. A description of the method is provided in the BA. (Exhibit SWRCB-104 Chapter 5, p. 5-197 to p.5-198.) Modeling is provided in Exhibit DWR-1074, file <Green sturgeon YCI for BA-BiOp_ICF_07072015.xlsx>.

e. CWF H3+ avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect unlisted salmonids and Pacific Salmon Essential Fish Habitat

i. **Salvage-Density Method (entrainment):** This method assessed south Delta entrainment risk for juvenile fall-run and late fall-run Chinook Salmon based on historic observations of salvage density (number of fish salvaged per volume of water exported, by month). The historic salvage density was multiplied by CalSim-II modeled exports to compare potential entrainment risk under the CWF H3+ and NAA scenarios. The method was used in the FEIR/S (an overview of the method is provided in the

FEIR/S Table 11-14 (Exhibit SWRCB-102, Section 11.3.2.1, p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.4, p.5.B-59; modeling is provided in Exhibit DWR-1074, files in folder <salvage_density_NMFS_FEIRS>) and the BA (a description is provided in the BA Appendix 5.D, Section 5.D.1.1.2.1, p.5.D-2; modeling is provided in Exhibit DWR-1074, files in folder <salvage_density_NMFS_BA>).

ii. **Delta Passage Model:** This model estimates juvenile Chinook Salmon survival through the Delta, by simulating entry and movement of the fish in the Delta day by day and estimating survival based on flow-survival relationships and migration pathways derived from tagging studies. Model inputs are from DSM2-HYDRO and daily-downscaled CalSim-II. A summary of the method is provided in the FEIR/S Table 11-16 (Exhibit SWRCB-102, Section 11.3.2.2, p. 11-230); details are provided in BDCP (Exhibit SWRCB-5) Appendix 5.C, Section 5C.4.3.2.2, p.5C.4-40 to 5.C.4-62. Modeling is provided in Exhibit DWR-1074, files in folder <DPM>.

3. Unlisted Fishes Covered by BDCP and Other Aquatic Species of Primary Management Concern

a. Avoidance and minimization measures, conservation measures and recommendations, and operational criteria generally will reasonably protect other unlisted fishes and other aquatic species of primary management concern from potential CWF H3+ effects in the Delta

i. **Salvage-Density Method (entrainment):** This method assessed south Delta entrainment risk for juvenile White Sturgeon, Sacramento Splittail, and Pacific and River Lamprey based on historic observations of salvage density (number of fish salvaged per volume of water exported, by month). The historic salvage density was multiplied by CalSim-II modeled exports to compare potential entrainment risk under the CWF H3+ and NAA scenarios. An overview of the method is provided in the FEIR/S Table 11-14 (Exhibit SWRCB-102, Section 11.3.2.1, p. 11-223), with more detailed description in the BDCP (Exhibit SWRCB-5) Appendix 5.B, Section 5.B.5.4 (p.5.B-59 to p.5.B-67). Modeling is provided in Exhibit DWR-1074, files in folder <salvage_density_FEIRS_unlisted>.

ii. **X2-Abundance/Survival Regressions:** This analysis estimated changes in juvenile Striped Bass, American Shad, and Bay Shrimp abundance or survival as a function of X2, an indicator of Delta outflow. The method used published relationships based on historic data between annual abundance indices of these species and average X2 during the early life stage. This relationship was applied to X2 from CalSim-II modeling to compare CWF H3+ and NAA scenarios. The methods are outlined in the FEIR/S, (Exhibit SWRCB-102, Section 11.3.4.2, p. 11-714, with regression coefficients provided by Kimmerer et al. (2009; Exhibit DWR-1091). Modeling is provided in Exhibit DWR-1074, files

<BDCP_EIR_EIS_X2_regressions_ALT4_H3_03232015.xlsx> and <BDCP_EIR_EIS_X2_regressions_ALT4_H4_03232015.xlsx>.

IV. CONCLUSION

On the basis of the testimony that I have provided, I reiterate my opinions regarding reasonable protection of the CWF H3+ for fish and other aquatic species:

- Construction effects from CWF H3+ will be avoided, minimized, and mitigated to reasonably protect Delta Smelt and Longfin Smelt;
- Implementing dual conveyance under CWF H3+ will maintain or potentially increase existing reasonable protection of Delta Smelt and Longfin Smelt from entrainment risk at the south Delta export facilities;
- The CWF NDD will reasonably protect Delta Smelt and Longfin Smelt through screening and habitat restoration mitigating potential restricted access to upstream areas;
- CWF H3+ will maintain existing reasonable protection of Delta Smelt fall rearing habitat;
- CWF H3+ will reasonably protect Longfin Smelt by implementing spring outflow criteria developed in coordination with the California Department of Fish and Wildlife;
- Other changes in Delta habitat from CWF H3+ operations will be limited or mitigated in order to reasonably protect Delta Smelt;
- Construction effects from CWF H3+ will be avoided, minimized, and mitigated to reasonably protect listed salmonids and Green Sturgeon;
- Implementing dual conveyance under CWF H3+ will maintain or potentially increase existing reasonable protection of listed salmonids and Green Sturgeon from entrainment risk at the south Delta export facilities;

- The CWF NDD will be screened and operated to meet salmonid protection standards and will be subject to numerous pre- and post-construction studies to provide reasonable protection of listed and salmonids and Green Sturgeon;
- CWF NDD bypass flow criteria, real-time operational adjustments, and mitigation will reasonably protect juvenile listed salmonids emigrating downstream in the Sacramento River;
- Construction and operation of the HORG will reasonably protect San Joaquin River basin salmonids;
- CWF H3+ operations will limit or mitigate potential changes in habitat suitability to reasonably protect listed salmonids and Green Sturgeon;
- CWF H3+ avoidance and minimization measures, conservation measures and recommendations, and operational criteria will reasonably protect unlisted salmonids and Pacific Salmon Essential Fish Habitat;
- Avoidance and minimization measures, conservation measures and recommendations, and operational criteria generally will reasonably protect other unlisted fishes and other aquatic species of primary management concern from potential CWF H3+ effects in the Delta.

Executed on this 29th day of November, 2017 in Sacramento, California.

Marin Greenwood

Marin Greenwood

REFERENCES

Kimmerer, W. J., E. S. Gross, and M. L. MacWilliams. 2009. Is the Response of Estuarine Nekton to Freshwater Flow in the San Francisco Estuary Explained by Variation in Habitat Volume? Estuaries and Coasts 32(2):375-389.

Stevens, D. E., H. K. Chadwick, and R. E. Painter. 1987. American shad and striped bass in California's Sacramento-San Joaquin River system. American Fisheries Society Symposium 1:66-78.

Turner, J. L. 1976. Striped bass spawning in the Sacramento and San Joaquin Rivers in Central California from 1963 to 1972. California Fish and Game 62(2):106-118.