EXHIBIT ARWA-900

TESTIMONY OF R. CRAIG ADDLEY, Ph.D

1. I have a Bachelor of Science degree in Fisheries and Wildlife, a Master of Science degree in Civil and Environmental Engineering, and a Doctor of Philosophy degree in Civil and Environmental Engineering from Utah State University, Logan, Utah. I have 30 years (1987 – Present) experience working on Water Supply and Hydropower Projects in the Western United States (California, Oregon, Washington, Alaska, Montana, Nevada, Arizona, and Utah). My expertise includes instream flows, hydrology, water temperature, hydrodynamics, and aquatic ecology, including temperature ecology and bioenergetics of fish (particularly endangered fish species). I have worked many years designing, modeling, and analyzing water resource project operations that provide resource benefits to people (hydropower, agriculture, municipal and industrial water supply) and natural ecosystems.

2. In California, I have worked on various rivers (such as the American, Klamath, Eel, Pit, Stanislaus, Yuba, Santa Ynez, Kaweah, and Rush Creek rivers) and for the past 10 years I have worked extensively in the American and Yuba river basins related to water supply, hydropower, and water rights. I have assisted Placer County Water Agency (PCWA) and the Sacramento Water Forum (Water Forum) in analyzing the hydrology and environmental effects of American River water resource operations on the Central Valley Project (CVP) and the State Water Project (SWP) and vice versa. I work as a Senior Consultant at Cardno, Sacramento. A copy of my qualifications is provided in **Exhibit ARWA-901**.

3. I assisted in the development of the Lower American River Modified Flow Management Standard (Modified FMS) on behalf of PCWA. I oversaw and participated in the development of various modeling tools, and provided various analyses and data sets, to support the Modified FMS's development. Those tools, analyses and data sets included the following:

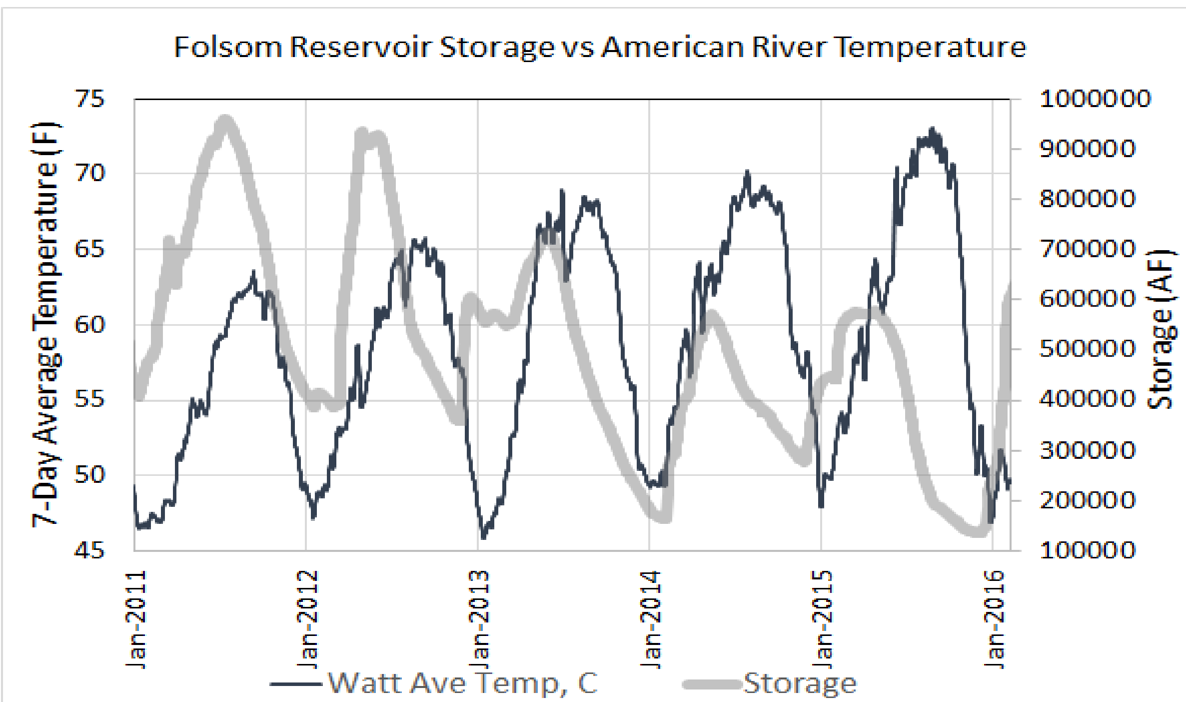
    - In coordination with PCWA, as described in Technical Memorandum 7, *Folsom Reservoir Inflow and Upstream Reservoir Storage for the 1922-2003 Period of Record*, we provided Folsom Reservoir inflow hydrology for input into CalSim II to the Water Forum and HDR for the 1922 to 2003 hydrological period of record;
    - We led the development of the American River Index (ARI), which is the water availability index used in the Modified FMS, as it is described in Technical Memorandum 1, *Project Description – Lower American River Modified Flow Management Standard;*
    - We led the development of the updated habitat suitability criteria and spawning habitat relationships in the Lower American River on which the Modified FMS is partially based;
    - We developed the water temperature modeling tools, including the following:
        - Technical Memorandum 4, *Folsom Reservoir Inflow Water Temperature Relationships*
        - Technical Memorandum 5, *Folsom Reservoir CE-QUAL-W2 Model and Calibration*
        - Technical Memorandum 6, *Lake Natoma CE-QUAL-W2 Model and Calibration*
        - Technical Memorandum 8, *Historical 1922-2003 Meteorological Dataset (Folsom Reservoir, Lake Natoma and Lower American River)*

- Technical Memorandum 9, *Lower American River Water Temperature Regression Relationships*

- We used the above water temperature modeling tools to help analyze the Modified FMS's effects on the Lower American River's temperatures downstream of Folsom and Nimbus Dams. Technical Memoranda 4 through 9 are **Exhibits ARWA-902** through **ARWA-907** to this testimony.

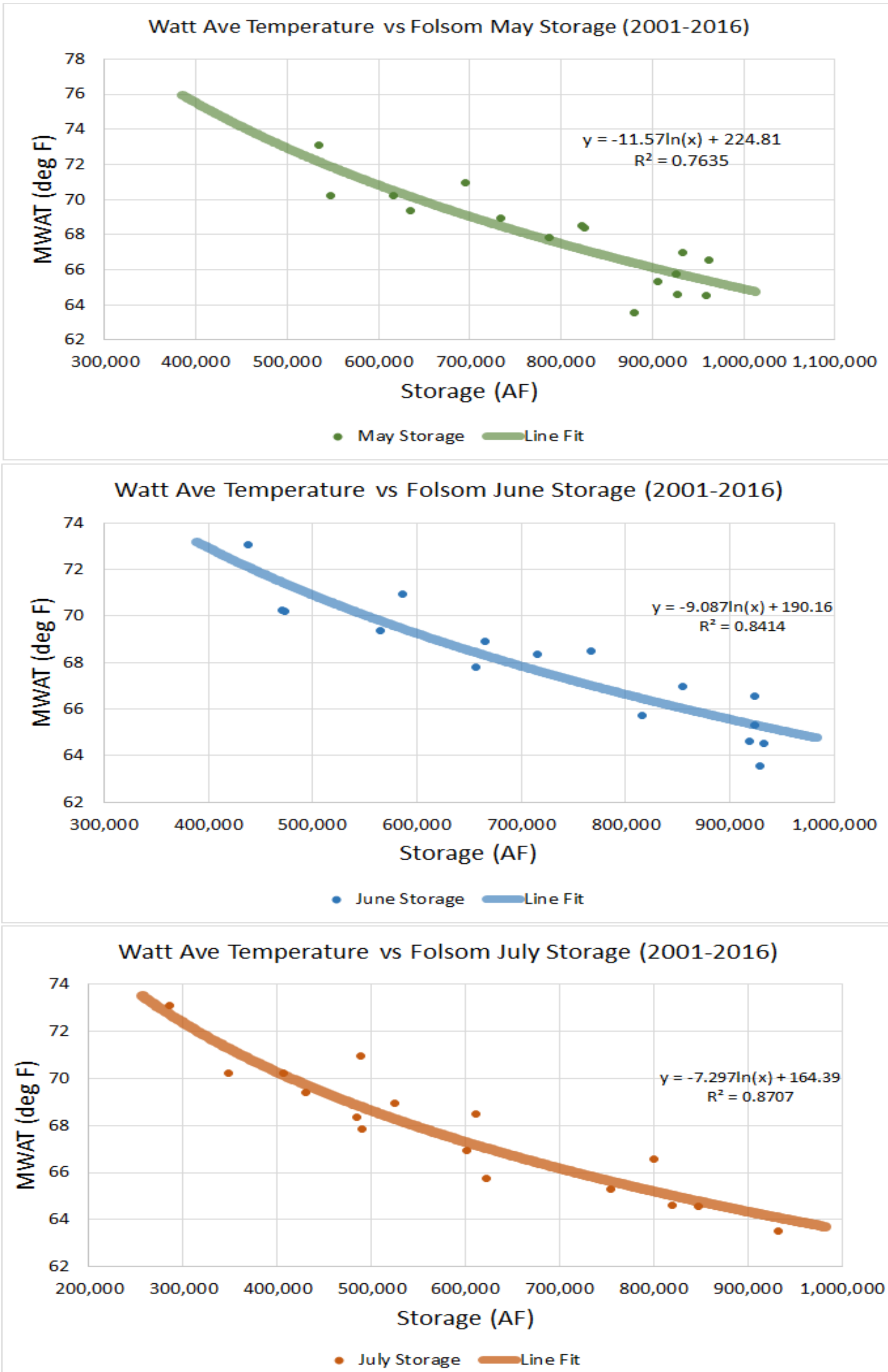
<u>Importance of Folsom Reservoir Storage to Lower American River Water Temperature</u>

4. Summer and fall water temperature in the Lower American River is particularly dependent on the amount of storage that accrues in Folsom Reservoir each year during spring and early summer (e.g., end-of-May). During the summer, hypolimnetic cold water is metered out of the reservoir into the American River through variable-elevation water intake shutters on each of Folsom Dam's three powerhouse penstocks. There is a strong inverse relationship between peak Folsom Reservoir storage and the corresponding summer and fall water temperature in the American River at Watt Avenue (river mile 9.2) (Figures 1 and 2). Higher peak storages generally result in cooler subsequent water temperature regimes (and lower peak storages result in warmer water temperatures).



(Data Sources: Folsom Storage data downloaded from CDEC Station FOL [Folsom Lake]; 7-day Average Temperature at Watt calculated from 15-minute data downloaded from CDEC Station AWB (Watt Avenue))

Figure 1. 2011 to 2016 Time series of Folsom Reservoir Storage (light gray) and Lower American River water temperature at Watt Avenue (dark) Showing the Inverse Relationship between Folsom Reservoir Storage and American River Water Temperature.



(Data Sources: Folsom Storage data downloaded from CDEC Station FOL [Folsom Lake]; Annual Maximum 7-day Average Temperature at Watt calculated from 15-minute data downloaded from CDEC Station AWB (Watt Avenue))

Figure 2. Folsom Reservoir Storage versus the Lower American River Water Temperature at Watt Avenue (maximum weekly average temperature, MWAT) (2001-2016).

5. Water temperature in the Lower American is a known stressor for anadromous salmonids (fall-run Chinook salmon and Federally- and State-listed Central Valley steelhead), particularly in the drier water years. For example, with respect to Central Valley steelhead, NMFS (2014, Appendix A, p. 17)[1] states, "Key stressors to steelhead in the American River include… warm water temperatures, particularly below dams, affecting juvenile rearing and outmigration and adult immigration and holding." Given that warm water temperature is an existing stressor on Lower American River anadromous salmonids, Folsom Reservoir operations that decrease water temperature in the Lower American River during warm water periods (e.g., Modified FMS) are beneficial to anadromous salmonids and operations that increase water temperature in the Lower American River produce additional stress on anadromous salmonids.

Operations and Modeling

6. CVP or SWP operations that result in decreased spring/early summer storage in Folsom Reservoir can directly impact the ability to manage water temperatures in the Lower American River. This includes operations within a given year that negatively affect storage or multi-year operations that leave storage low at the end of one year and create low storage during the spring/early summer of the following year (particularly during drought years).

7. Some other factors that affect water temperature in the Lower American River include the volume and temperature of inflows to Folsom Reservoir; operation of the penstock variable-intake shutters at Folsom Dam; cold water leakage from those shutters; timing and volume of releases from Folsom Reservoir; warming of water through Lake Natoma; meteorological conditions; and discharge from Nimbus Dam.

8. The water temperature modeling tools identified above (paragraph 3) accurately capture the physical processes described in paragraphs 6 and 7 that determine water temperature in the Lower American River. These tools were used as part of the development of the Modified FMS. I oversaw and participated in the water temperature modeling for the Modified FMS and reviewed the results of that modeling.

9. **Exhibit ARWA-908** is a compilation of the key temperature modeling results for the Modified FMS that derive from the work described in paragraph 8 using the tools described in paragraph 3. Based on the modeling, the Modified FMS, as compared to the existing 2006 FMS, provides consistently cooler water temperature in the Lower American River during the summer, warm water months and in the drier, warmer water years (e.g., <25-30% exceedance values in **Exhibit ARWA-908**).

Conclusions Concerning Lower American Water Temperatures and the Modified FMS

10. I contributed to the preparation of the *Biological Rationale, Development and Performance of the Modified Flow Management Standard*, which describes in detail the biological rationale for the Modified FMS's elements. The Modified FMS includes Folsom Reservoir storage requirements that were carefully designed to maintain both within- and between-year storage in

[1] National Marine Fisheries Service. 2014. Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central valley Spring-Run Chinook Salmon and the Distinct Population Segments of California Central Valley Steelhead. West Coast Region, Sacramento, California.

Folsom Reservoir (e.g., end-of-May, end-of-December). Those storage requirements were scaled to annual hydrology (i.e., available run-off) in the American River each year, as depicted in the ARI, and to minimum release requirements (MRR) in the Lower American River. The Modified FMS's Folsom Reservoir storage requirements and MRRs were specifically designed to ensure water temperatures in the Lower American River are maintained or enhanced and protected in the future without affecting environmental conditions at other locations, such as for salmon in the Sacramento River.

11. It is my professional opinion based on a thorough review and extensive testing and modeling of the Modified FMS that it protects water temperature conditions in the Lower American River for anadromous salmonids.

12. **Exhibit ARWA-501** is a joint PowerPoint presentation that summarizes key points of my testimony. That exhibit represents the "summary of testimony" requested for this hearing.