

Exhibit DWR-653

REPORT ON THE EFFECTS OF THE CALIFORNIA WATERFIX ON  
HARMFUL ALGAL BLOOMS IN THE DELTA

*Prepared for:*

CALIFORNIA DEPARTMENT OF WATER RESOURCES

*Prepared by:*



March 2017

STKN-034

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# TABLE OF CONTENTS

SECTION	PAGE
1 QUALIFICATIONS .....	1
2 PURPOSE AND ORGANIZATION OF REPORT .....	1
3 ENVIRONMENTAL FACTORS AFFECTING HARMFUL ALGAE BLOOMS .....	2
3.1.1 Life History .....	3
3.1.2 Temperature .....	4
3.1.3 Flows and Residence Time.....	4
3.1.4 Irradiance .....	5
3.1.5 Nutrients .....	6
3.1.6 Toxins .....	6
4 HABS WITHIN THE DELTA.....	7
4.1 Assessment of HABS in EIR/EIS .....	7
4.1.1 Use of Models for Delta HAB Formation.....	7
4.1.2 Microcystis vs. Other HABS .....	9
4.1.3 Spring as an Important Bloom Period .....	9
4.2 River Flows and Velocity Effects of the CWF .....	10
Sacramento River at Freeport .....	13
Lower Sacramento River at Rio Vista .....	14
San Joaquin River at Brandt Bridge and Antioch .....	16
San Joaquin River at Buckley Cove .....	19
Old River at Tracy Road.....	21
Grant Line Canal .....	23
Middle River at Bacon Island.....	25
Old River at Rock Slough .....	27
Old River at Highway 4.....	29
4.3 Residence Time Effects of the CWF .....	31
4.4 Temperature Effects of the CWF.....	33
Lower Sacramento River at Rio Vista .....	34
San Joaquin River at Prisoners Point.....	35
San Joaquin River near Stockton Deep Water Ship Channel .....	35
San Joaquin River at Brandt Bridge .....	35
4.5 Turbidity Effects of the CWF .....	36
4.6 Nutrient Effects of the CWF.....	38
5 REFERENCES .....	39

## LIST OF FIGURES

Figure 1. Probability of exceedance of daily maximum velocity in the lower Sacramento River at Freeport for the 1976–1991 period of record modeled.....	14
Figure 2. Probability of exceedance of daily maximum velocity in the lower Sacramento River at Rio Vista for the 1976–1991 period of record modeled.....	15
Figure 3. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the lower Sacramento River at Rio Vista during the months June through November for the 1976–1991 period of record modeled.....	15
Figure 4. Probability of exceedance of daily maximum velocity in the San Joaquin River at Brandt Bridge for the 1976–1991 period of record modeled.....	17
Figure 5. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the San Joaquin River at Brandt Bridge during the months June through November for the 1976–1991 period of record modeled.....	17
Figure 6. Probability of exceedance of daily maximum velocity in the San Joaquin River at Antioch for the 1976–1991 period of record modeled.....	18
Figure 7. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the San Joaquin River at Antioch during the months June through November for the 1976–1991 period of record modeled.....	18
Figure 8. Probability of exceedance of daily maximum velocity in the San Joaquin River at Buckley Cove for the 1976–1991 period of record modeled.....	20
Figure 9. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the San Joaquin River at Buckley Cove during the months June through November for the 1976–1991 period of record modeled.....	20
Figure 10. Probability of exceedance of daily maximum velocity in the Old River at Tracy Road for the 1976–1991 period of record modeled.....	22
Figure 11. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Old River at Tracy Road during the months June through November for the 1976–1991 period of record modeled. ....	22
Figure 12. Probability of exceedance of daily maximum velocity in the Grant Line Canal for the 1976–1991 period of record modeled.....	24
Figure 13. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Grant Line Canal during the months June through November for the 1976–1991 period of record modeled.....	24
Figure 14. Probability of exceedance of daily maximum velocity in the Middle River at Bacon Island for the 1976–1991 period of record modeled.....	26
Figure 15. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Middle River at Bacon Island during the months June through November for the 1976–1991 period of record modeled.....	26
Figure 16. Probability of exceedance of daily maximum velocity in the Old River at Rock Slough for the 1976–1991 period of record modeled.....	28
Figure 17. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Old River at Rock Slough during the months June through November for the 1976–1991 period of record modeled. ....	28

Figure 18. Probability of exceedance of daily maximum velocity in Old River at Hwy 4 for the 1976–1991 period of record modeled.....30

Figure 19. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Old River at Hwy 4 during the months June through November for the 1976–1991 period of record modeled.....30

## APPENDICES

Appendix A Delta Monthly Mean Temperatures at Nine Delta Locations for the CWF and NAA.

## ACRONYMS AND ABBREVIATIONS

BDCP	Bay Delta Conservation Plan
C	Celsius
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CWF	California WaterFix
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
EIR/EIS	Environmental Impact Report/Environmental Impact Statement
F	Fahrenheit
ft/s	feet per second
HABs	harmful algal blooms
NAA	No Action Alternative
NEPA	National Environmental Policy Act
N:P	nitrogen:phosphorus
RBI	Robertson-Bryan, Inc.
RDEIR/SDEIS	Recirculated Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement
USGS	United State Geological Survey

## 1 QUALIFICATIONS

My name is Dr. Michael Bryan. I am a Principal Scientist and Managing Partner at Robertson-Bryan, Inc. (RBI). I received a Bachelor of Science degree in Fisheries Biology from the University of Wisconsin-Stevens Point in 1986, a Master of Science degree in Fisheries Biology from Iowa State University in 1989, and a Doctor of Philosophy degree in Toxicology and Fisheries Biology from Iowa State University in 1993.

I have 23 years of experience in assessing impacts of water resource projects on water quality and aquatic biological resources in California. My expertise includes assessing measured and modeled data developed to characterize the environmental effects of projects for determining impacts to beneficial uses of waters throughout northern California, with a focus on Central Valley water bodies from Shasta Reservoir to the Sacramento-San Joaquin Delta (Delta). I have worked closely with the Central Valley Regional Water Quality Control Board over the past two decades to assist in developing and adopting eight new water quality objectives for the Central Valley Water Quality Control Plan (Basin Plan). For the California WaterFix (CWF), I led a team of scientists and engineers at RBI in the preparation of the Water Quality Chapter of the Environmental Impact Report/Environmental Impact Statement (EIR/EIS).

My responsibilities at RBI include serving as the Firm's Managing Partner and technical lead for the practice areas of water quality, fisheries biology, and California Environmental Quality Act/National Environmental Policy Act documentation. Prior to my work at RBI, I was employed by Surface Water Resources, Inc., where I used modeling output from hydrologic models (e.g., PROSIM and CALSIM), temperature models (e.g., Bureau of Reclamation's [Reclamation] lower Sacramento River and lower American River temperature models), and salmon early life stage mortality models (e.g., Reclamation's mortality models for the lower Sacramento and American rivers) along with other studies and monitoring data to assess the potential impacts of water diversion and reservoir and dam re-operation projects on water quality and fish resources in the State Water Project and Central Valley Project reservoirs, rivers and Delta. My expertise also includes designing and implementing field and modeling studies to evaluate the impacts of wastewater treatment plant discharges on receiving water beneficial uses. A copy of my statement of qualifications has been submitted as Exhibit DWR-33.

## 2 PURPOSE AND ORGANIZATION OF REPORT

Testimony provided primarily by Mr. Erik Ringelberg on behalf of the County of San Joaquin, San Joaquin County Flood Control and Water Conservation District and Mokelumne River Water and Power Authority, and Local Agencies of the North Delta, South Delta Water Agency and Central Delta Water Agency [Exhibit SJC 004], and more generally reiterated by Janet McCleary [Exhibit SCDA-62-errata, Frank Morgan [Exhibit SCDA-61-errata], Michael Broadsky [Exhibit SCDA-60-errata], and Tom Burke [Exhibit SCDA-35; Exhibit SDWA-76], Tim Stroshane [Exhibit RTD-10-rev2] and Barbara Barrigan-Parrilla [Exhibit RTD-20], and Fred Lee [Exhibit CSPA-6-Revised] raised concerns regarding the potential for the CWF to result in more frequent harmful algal blooms (HABs) within the Delta. Testimony regarding

HABs provided by Mr. Ringelberg focused primarily on the cyanobacteria *Microcystis aeruginosa*.

This report has been prepared as the technical basis for the expert opinions that I present in my rebuttal testimony regarding the degree to which the CWF would affect HABs within the Delta, with emphasis on *Microcystis aeruginosa* blooms. Specific claims being rebutted by this testimony are quoted under various sections below, followed by evidence supporting my expert opinions on the issues addressed.

Section 3 provides an overview on the environmental factors that trigger the emergence of the most commonly studied HAB genera in Central California – *Microcystis*. Section 4 provides a rebuttal of claims that the CWF would cause an increase in HABs in the Delta, due to increased water temperatures, nutrient effects, decreased flows and turbulence and associated increased residence time, and decreased turbidity. In this section, I provide a detailed assessment of how the CWF could affect river water temperature, river velocity, and turbidity and how such changes in these physical parameters could, in turn, affect HABs in the Delta. In addition, this section provides rebuttal to Mr. Ringelberg’s claims that the CWF EIR/EIS should have used models to assess the effects of the project on Delta HABs, that the EIR/EIS analysis should have discussed genera of cyanobacteria other than *Microcystis*, and that the spring is an important time-period for HABs in the Delta.

Since *Microcystis aeruginosa* generally dominates cyanobacteria blooms in the Delta, and cyanotoxins are primarily associated with *Microcystis* (Lehman et al. 2010, 2017; Kudela et al. 2015), most Delta research has focused on *Microcystis aeruginosa* (Kurobe et al. 2013, Lehman et al. 2013, Berg and Sutula 2015) Thus this technical report primarily focuses on *Microcystis*, but will reference other cyanobacteria genera when appropriate.

### 3 ENVIRONMENTAL FACTORS AFFECTING HARMFUL ALGAE BLOOMS

Cyanobacteria (also commonly called blue-green algae) are a phylum of bacteria that obtain their energy through photosynthesis. The name "cyanobacteria" comes from their color (Greek: “kyanós” meaning “blue”). Cyanobacteria perform photosynthesis in folds within the outer membrane of the cell, rather than within chloroplasts like many other eukaryotic algae. The term cyanoHABs refers to cyanobacteria such as *Microcystis*, *Anabaena*, *Aphanizomenon*, *Oscillatoria* and other genera that can produce harmful algal blooms. The most common and well studied cyanoHAB in the Delta is due to *Microcystis*.

This section is included in this report to provide an overview of the scientific understanding of the primary environmental factors that trigger the emergence and subsequent growth of *Microcystis*. Although focused on *Microcystis spp.*, based on the abundance of scientific study of this genera of cyanobacteria, much of the information pertaining to this genera also pertains to *Anabaena* and other cyanobacteria. The information presented here is used as the technical basis from which I rebut the claims regarding effects of the CWF on cyanoHABs within the Delta.



### 3.1.1 Life History

Toxin producing cyanobacteria have been observed in the Delta since 1999 (Lehman et al. 2005). These blooms are primarily comprised of *Microcystis aeruginosa*. In the Delta, scums are primarily composed of the colonial form of *Microcystis*, but single cells are also present (Baxa et al. 2010). Other pelagic cyanobacteria including *Aphanizomenon* spp., *Anabaena* spp. (recently renamed *Dolichospermum*) and *Oscillatoria* have also been detected in the Delta, although generally to a lesser extent than *M. aeruginosa* (Lehman et al. 2010, Spier et al. 2013, Mioni et al. 2012, Berg and Sutula 2015). From August through October 2011, *Aphanizomenon* was identified as the most common cyanobacteria genus in the Delta (Mioni et al. 2012); however, the species of *Aphanizomenon* that has been shown to occur in the Delta is typically not toxic, so when this species is present, it is considered more of a nuisance than harmful to humans and wildlife (Kudela et al. 2015).

*Microcystis* has an annual life cycle characterized by two phases. The first is a benthic phase, during which cysts overwinter in the sediment. In the second planktonic phase, which occurs during the summer and early fall months, *Microcystis* enters the water column and begins to grow. When environmental conditions, such as sufficiently warm water temperatures, trigger *Microcystis* recruitment from the sediment, the organism is resuspended into the water column (Verspagen et al. 2004, Mission and Latour 2012).

There are five primary environmental factors that trigger the emergence and subsequent growth of *Microcystis* in the water column of Delta waters, which are:

1. Water temperatures  $>19^{\circ}\text{C}$  ( $66.2^{\circ}\text{F}$ ),
2. Low flows and channel velocities resulting in low turbulence and long residence times,
3. Water column irradiance and clarity  $>50$  micromoles per square meter per second ( $\mu\text{moles}/\text{m}^2/\text{s}$ ),
4. Sufficient nutrient availability (nitrogen and phosphorus), and
5. Salinity below 10 ppt.

Although the factors listed above are positively related to *Microcystis* abundance throughout the Delta (Jassby 2005, Lehman et al. 2013, Berg and Sutula 2015, Preece et al. 2017), substantial uncertainty exists with regards to how interaction of these factors result in blooms. To determine the exact processes and interactions of factors that affect development of *Microcystis* blooms in the Delta, additional studies that investigate hydraulic processes and water quality are required (Lehman et al. 2015).

Compared to other phytoplankton species, *Microcystis*, has a relatively slow growth rate (Mur et al. 1999). *Microcystis* blooms typically develop over a period of several weeks after cells emerge from the benthic state (Marmen et al. 2016). Because environmental conditions and benthic recruitment drive *Microcystis* formation within the water column, it is common for many *Microcystis* cells to enter the water column at the same time. Like many cyanobacteria species, *Microcystis* possess specialized intracellular gas vesicles that enable the organism to regulate its

buoyancy (Reynolds 1981, as cited in Paerl et al. 2014). This buoyancy allows *Microcystis* to take advantage of near surface areas with optimal growth conditions (e.g., light). Cells collect at the water surface to form colonies and the collection of colonies come together to form a mat or “scum layer,” primarily in calm waters, because turbulent waters prevent this phenomenon from occurring. The collection of cells and colonies at the water surface in calm water environments allows *Microcystis* to sustain a competitive advantage over other phytoplankton species by optimizing their photosynthetic needs for light (by being at the water surface) while shading out other algal species that they compete with for nutrients and light via the formation of mats or “scum layers” at the surface (Huisman et al. 2004). Once in the water column, and when environmental conditions are favorable, *Microcystis* multiplies. One study found the doubling time of 32 *Microcystis aeruginosa* strains ranged from 1.5 to 5.2 days, with an average doubling time of 2.8 days (Wilson et al. 2006).

### 3.1.2 Temperature

Cyanobacteria usually bloom during the summer and early fall when water temperatures are warm. Several studies have found 20°C was the threshold for cyanobacterial growth (Dupuis and Hann 2009, Neuheimer and Taggart 2007 as cited in Rolland et al. 2013). The only available regional temperature threshold information for cyanobacteria is for *Microcystis* (Lehman et al. 2008, 2013), which is 19°C (66.2°F). Temperature is considered the primary factor that typically restricts *Microcystis* development to the summer and early fall months in water bodies of the region (Lehman et al. 2013). Cyanobacteria generally require temperatures above 25°C (77°F) to be competitive with diatoms and temperatures above 20°C (68°F) for growth rates to compete with other algae species (Berg and Sutula 2015). In temperate latitudes, optimal cyanobacteria growth usually occurs between temperatures of 25°C (77°F) and 35°C (95°F) (Reynolds 2006, Lürling et al. 2013). Evidence suggests cyanobacteria growth rates double when temperatures increase from 20°C (68°F) to 27°C (80.6°F) (Lürling et al. 2013, Berg and Sutula 2015).

### 3.1.3 Flows and Residence Time

Because *Microcystis* has a relatively slow growth rate long residence times are required for cells to accumulate and form significant blooms (Reynolds 1997 as cited in Lehman et al. 2008, Lehman et al. 2013, 2015). Wind and tides can also enhance the aggregation of *Microcystis* cells in slow moving waters (Baxa et al. 2010). Since flushing rates determine residence time, lower channel velocities increase residence time and decrease cyanobacteria loss rates (Romo et al. 2013). Several studies have found longer residence times are positively related to cyanobacteria abundance (Elliott 2010, Romo et al. 2013, Lehman et al. 2017). For example, in the extreme drought year of 2014, Lehman et al. (2017) found long residence times were one factor affecting the magnitude of *Microcystis* blooms within the Delta. Other studies demonstrate that long residence time alone does not cause cyanobacteria blooms to form, even when other environmental conditions are suitable for a bloom. This was exemplified in the Stockton Deep Water Ship Channel, where there are long summer residence times. Here, a three year study documented a large persistent *Microcystis* bloom in 2012 but not in 2009 or 2011 (Spier et al. 2013). Environmental conditions were similar in 2012 and 2009 and *Microcystis* cells were present in 2009, yet no bloom formed in 2009. No specific environmental factor could be

attributed to the 2012 bloom (Spier et al. 2013). This suggests *Microcystis* ecology and competition with other algae is complex, and longer residence times do not necessarily indicate that a bloom will form.

In faster moving, turbulent waters, the ability of *Microcystis* to maintain its positive buoyancy is reduced (Visser et al. 1996). Therefore, higher flow rates (and associated higher channel velocities and turbulence) make it difficult for *Microcystis* to form dense collections of colonies at the water surface. Turbulence affects metabolic processes and cell division (Koch 1993, Thomas et al. 1995, as cited in Li et al. 2013) and thus can be a negative growth factor (Paerl et al. 2001). Moreover, turbulent water mixes all algae throughout the photic zone of the water column and reduces light through turbidity which allows faster growing chlorophytes (green algae) and diatoms to outcompete the slower growing cyanobacteria, including *Microcystis* (Wetzel et al. 2001, Huisman et al. 2004, Li et al. 2013). The magnitude of water velocity required to disrupt *Microcystis* blooms varies substantially by system. Although this information is not specifically available for Central Valley waters, a number of studies report critical velocity rates that disrupt *Microcystis* blooms to be in the 0.1 to 1.3 ft/s range (Mitrovic et al. 2003, Zhang et al. 2007, Long et al. 2011, as cited in Zhang et al. 2015, Mitrovic et al. 2011, Li et al. 2013). For example, in the lower Darling River, Australia, velocities above 1.0 ft/s were shown to quickly disrupt an established cyanobacteria bloom (Mitrovic et al. 2011). In the Zhongxin Lake system China, flow velocities of 0.2 to 1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015). This information from the scientific literature is consistent with what we see in the Central Valley regarding where *Microcystis* blooms often occur (i.e., in calm, low velocity, non-turbulent aquatic environments) (Lehman et al. 2005, 2008, 2013; Berg and Sutula 2015), and where they typically do not occur (i.e., in riverine channels having higher velocities and turbulent flow) (Lehman et al. 2013).

#### 3.1.4 Irradiance

Irradiance plays a critical role in cyanobacteria buoyancy control (Walsby et al. 2004), growth rates, and triggering vertical migration of over-wintering cyanobacteria cells from the sediment. Relatively high irradiances ( $>50 \mu\text{mol photons m}^{-2} \text{ s}^{-1}$ ) have been found to promote maximal cyanobacteria growth rates in the Delta (Berg and Sutula 2015) and are considered a prerequisite for *Microcystis* and *Anabaena* bloom formation (Tsumimura and Okubo 2003, Lehman et al. 2013). Cyanobacteria generally grow ineffectively in well mixed, low light waters, although certain genera (i.e. *Anabaena* and *Cylindrospermopsis*), can grow well in constant low light conditions (Litchman 1998). Other genera, such as *Microcystis* have high light requirements and, thus cannot become dominant in light limited conditions (Huisman 1999). Diatoms are generally more adapted to low light conditions and dominate phytoplankton communities during periods of low average irradiance with high light fluctuations (Reynolds 1994 as cited in Litchman 1998, Litchman 1998). For example, diatoms keep near maximal growth rates in irradiances less than  $50 \mu\text{mol photons m}^{-2} \text{ s}^{-1}$  (Berg and Sutula 2015). Since cyanobacteria have poor light absorption efficiency in well mixed environments (Reynolds 2006), fluctuating light levels in turbulent waters, conditions often present in spring months, favor diatoms (Reynolds 1983, Kiorboe 1993 as cited in Litchman 1998, Reynolds 2006). Green algae and cyanobacteria can both dominate in

high light conditions; however, *Microcystis* and *Anabaena* can use their buoyancy to migrate to the water surface where light is available and utilize high irradiance levels that inhibit other phytoplankton species (Wu et al. 2011 as cited in Lehman et al. 2013).

### 3.1.5 Nutrients

Nutrients (nitrogen and phosphorus) within the Delta are available annually at levels that are non-limiting to the growth of *Microcystis* (Lehman et al. 2017). With optimal temperatures, flows and residence time, and irradiance, *Microcystis* (and other cyanobacteria) biomass is proportional to nutrient (i.e., nitrogen and phosphorus) availability in the water column (Berg and Sutula 2015). However, recent literature suggests that levels of nitrogen, phosphorus, or their N:P ratio do not control the seasonal or inter-annual bloom variation within the Delta (Lehman et al. 2005, 2008, 2013, 2017; Berg and Sutula 2015). In fresh water bodies, cyanobacteria growth is often associated with excessive phosphorus loading and growth is generally limited by phosphorus rather than nitrogen (Schindler et al. 2008). However, some studies have found total nitrogen alone is the limiting nutrient for algal growth in freshwater bodies (Levine and Whalen 2001). Thus, both phosphorus and nitrogen are important in promoting cyanobacteria growth and subsequent blooms, as is the case with other algae. In general, nutrients typically become limiting to phytoplankton when concentrations fall below 0.07 mg/L dissolved inorganic nitrogen (nitrite, nitrate and ammonia) and 30 µg/L dissolved phosphorus (orthophosphate or soluble reactive phosphorus, Jassby 2005). The amount of total phosphorus in a water body is a fundamental basis for cyanobacteria growth, but concentrations below 100 µg/L are unlikely to cause mass cyanobacteria blooms (Chorus and Cavalieri 2000, World Health Organization 2011). In reviews of stream ecosystems, lakes and reservoirs, total nitrogen concentrations of 0.7-1.5 mg/L were found to support cyanobacteria growth (Dodds et al. 1998).

### 3.1.6 Toxins

The cyanobacteria toxin, microcystin, was first documented in the Delta in 2003 (Lehman et al. 2005) and has been detected on numerous occasions since (Lehman et al. 2008, 2010, 2013, 2015, 2017; Spier et al. 2013) with increased toxin concentrations generally associated with higher *Microcystis* abundances (Lehman et al. 2013). During the 2014 drought microcystin concentrations were the highest on record for the Delta, frequently exceeding both the World Health Organization (1 µg/L) and Environmental Protection Agency (0.3 µg/L for children under the age of 6) drinking water guidelines (Lehman et al. 2017). Cyanobacteria produce a number of cyanotoxins. In Central California, toxins other than microcystins are not frequently detected (Gibble and Kudela 2014, Berg and Sutula 2015). Like other regions where *Microcystis* occurs, a mix of toxigenic and non-toxigenic strains occurs in the Delta (Baxa et al. 2010). Toxigenic strains and appropriate environmental conditions must be present for microcystin to occur (Marmen et al. 2016). Production of microcystins associated with *Microcystis* blooms is highly variable and not well understood. Nevertheless, *Microcystis* blooms often produce microcystin (Lehman et al. 2015).

## 4 HABS WITHIN THE DELTA

Mr. Erik Ringelberg, and the others mentioned in the beginning of the report, made numerous statements in their written [e.g. Exhibit SJC-004] or oral testimony [e.g. 11-17-16 and 11-30-16 Transcripts] pertaining to the effect of the CWF on HABS in the Delta that are not based on analyses or independent studies. Thus, his claims that the CWF would cause temperatures and flows to be more conducive to harmful algae bloom formation in the Delta are unsupported. This section provides information and assessment that serve as the technical basis for my rebuttal of key statements from Mr. Ringelberg's testimony.

### 4.1 ASSESSMENT OF HABS IN EIR/EIS

#### 4.1.1 Use of Models for Delta HAB Formation

In his written and oral testimony, Mr. Ringelberg claims the project proponents should have used models to assess the effects of the CWF on Delta HABS. For example, he stated: "...it's not rocket science to produce flow-bloom relationships, and it should be done." [Transcript vol. 29, pg. 50, Ln. 8–12]. In his written testimony, Mr. Ringelberg states: "Given the wide range of uncertainty regarding the ultimate climate change trajectory, and the temporal difference between when the project is proposed and the more significant impacts of that change in the Delta, the project should use or develop a model for HABS and their formation processes in the Delta, and then provide model support to demonstrate how it will not induce HABS through its operations over the next 20 years." [Exhibit SJC-004, pg. 13, Ln. 19–23]. Mr. Ringelberg also states: "There is a detailed Delta food web model, as well as predictive models used for the Potomac and Lake Erie<sup>1</sup>. (SJC-046 Durand, 2008, SJC-047 Tango 2009) The project failed to apply any of those models to this project." [SJC-004, pg. 3, Ln. 7-10].

***At this time there is no model to predict Microcystis blooms in the Delta. It will take years of work to develop such a model because there is not sufficient information available currently to develop a predictive, environmental parameter-driven Microcystis model for the Delta. Consequently, the project proponents did not error by not using a model to predict the effects of the CWF on HABS in the Delta because no such model is available to do so.***

A substantial amount of field data are required to develop, calibrate, and verify flow-bloom relationships, and such relationships would be expected to vary by site within the Delta due to complex hydrodynamics and how flows affect channel velocity, turbulence, and residence time, and interact with nutrients, turbidity, and temperature, which also affect HABS. At this time there is not sufficient information available to develop a flow-bloom model. For example, C. Mioni has been attempting to develop hydrodynamic models to predict harmful algal bloom occurrences (Berg and Sutula 2015). Mioni has determined there are no clear physical drivers related to cell or cyanotoxin abundance and that further monitoring and modeling is necessary to develop a complex model to predict HABS development (Berg and Sutula et al. 2015). Furthermore, the Central Valley Regional Water Quality Control Board, the California Environmental Protection Agency, and State Water Resources Control Board have proposed

developing a work plan for a modeling strategy, model data requirements, and an implementation strategy for HABs within the Delta (Berg and Sutula 2015). Hence, based on the current state of the science regarding HABs in the Delta, it was not possible for DWR/Reclamation to develop and use a calibrated and verified model to evaluate flow-bloom relationships within the Delta. Such models were not available at the time the CWF EIR/EIS was prepared, they are not available presently, and will not likely be available for years to come.

Later in his testimony, Mr. Ringelberg contradicts his own statements cited above by stating that the development of a flow-HAB model for the Delta would be complex and that much work needs to be done to develop such a model. Specifically, he stated: “*Algae dynamics are literally dynamic. They change spatially; they change temporally; there's lots of moving parts in terms of the actual variables on that. We need to spend a lot more time, a lot more energy, setting up monitoring, looking at a couple factors, developing models, testing those models, working those models out so we can catch up with places like the Potomac, because we have the ability to do so.*” [Transcript vol. 29, pg. 58–59, Ln. 21–25, 1–2]. Further, he agrees that the data currently does not exist to develop these models. This is illustrated in his conversation with Ms. Ansley: “*MS. ANSLEY: So this model doesn't specifically provide any information regarding the level of flows that were initiated or maintain a microcystis bloom in the Delta. WITNESS RINGELBERG: To the best of my knowledge, those data don't exist.*” [Transcript vol. 29, pg. 90–91, Ln. 21–25, 1]. Hence, Mr. Ringelberg acknowledges here that models are not currently available to predict HABs in the Delta, and that substantial efforts are required to develop such models. Moreover, by the above-cited statement, he also acknowledges that we cannot simply apply a model developed for the Potomac River to the Delta, but rather have to develop Delta-specific models. Mr. Ringelberg referenced additional models of Durand, 2008 and Tango 2009, which are not applicable to the Delta. Efforts are ongoing by DWR, the Central Valley Regional Water Quality Control Board, the California Environmental Protection Agency, the State Water Resources Control Board and others to collect the field data necessary to develop such models.

Mr. Ringelberg's use of DRERIP (or Delta Food Web Model) is inappropriate because it does not address cyanobacteria. Mr. Ringelberg acknowledges in his oral testimony that the DREIP model does not apply to cyanobacteria. This is illustrated in his conversation with Ms. Ansley. “*WITNESS RINGELBERG: Well, it actually breaks out phytoplankton to finer scales, but it does not, I think to your next question, identify specific blue-green algae. MS. ANSLEY: Correct. It focuses on diatoms and microflagellates? WITNESS RINGELBERG: That's correct.*” [Transcript vol. 29, pg. 89, Ln. 5-11]. Mr. Ringelberg also agrees that the DRERIP model does not provide any information related to flows and *Microcystis* blooms. “*MS. ANSLEY: So this model doesn't specifically provide any information regarding the level of flows that were initiated or maintain a microcystis bloom in the Delta. WITNESS RINGELBERG: To the best of my knowledge, those data don't exist.*” Mr. Ringelberg also incorrectly states the United States Geological Survey (USGS) has completed or is working on a modeling exercise for HABs. “*There are other elements to algal growth that I talked about, lights and different nutrient ratios. That's a more sophisticated modeling exercise. That can also readily be done with the information we have today. The USGS is doing that.*” [Transcript vol. 29, pg. 50, Ln. 13–17]. Although the USGS is currently collecting water quality and hydrodynamic data to develop a more complete

understanding of changes in the Delta's physical, chemical and biological environment, to the best of my knowledge, the agency is not developing a model to predict HABs.

At this time there is no model to predict *Microcystis* blooms in the Delta (Berg and Sutula 2015), and it will take years of work to develop such a model. Consequently, the project proponents did not error by not using a model to predict the effects of the CWF on HABs in the Delta because no such model is available to do so. Without a model being available, the CWF Recirculated Draft EIR/Supplemental Draft EIS (and Final EIR/EIS published in December 2016) identified what is known about the key drivers of *Microcystis* blooms in the Delta, and evaluated how the CWF could affect those drivers and thus how the CWF would be expected to affect *Microcystis* blooms in the Delta.

#### 4.1.2 *Microcystis* vs. Other HABs

Mr. Ringelberg also claims the project proponents should not have looked at only a single HAB genera (*Microcystis*): “Where there is any project analysis regarding HABs, the project impacts are largely ignored, and, instead, what limited analysis exists is solely and incorrectly focused on the nutrient data, and their relationship to the blooms of a single species, *Microcystis aeruginosa*. (SCWRB-3 RESIRC 2622 Pg. 14-20)” [Exhibit SJC-004, pg. 5, Ln. 15–18]. Mr. Ringelberg also claims; “The--the focus on a single, readily understood organism, microcystis is a diversion away from the other microcystin and other algal toxin creating blue-green algae or microbacteria and have the potential of creating multiple kinds of algal blooms with different kinds of toxicity, different rations, different mixes of different toxins.” [Transcript vol. 29, pg. 100, Ln. 1-8].

As discussed above in Section 3, HABs in the Delta and its tributaries are primarily comprised of *Microcystis aeruginosa*. Although *Aphanizomenon spp.* and *Anabaena spp.* (recently renamed *Dolichospermum spp.*), and *Oscillatoria spp.* have also been detected in the Delta (Lehman et al. 2010, Mioni et al. 2012), there is limited information available on these genera. Therefore, most Delta research has focused on annual *Microcystis* blooms (Kurobe et al. 2013, Lehman et al. 2013). For example, in their report titled: “Factors Affecting Growth of Cyanobacteria with Special Emphasis on the Sacramento-San Joaquin Delta,” Berg and Sutula (2015) state (p. 35, paragraph 3): “Because *Aphanizomenon* and *Anabaena* densities have only been documented for two time points, the following sections will focus on *Microcystis* biomass and microcystin toxin concentrations.” Furthermore, cyanotoxins other than microcystin are not frequently encountered in the Delta. Hence, because most of the HAB data available for the Delta is associated with *Microcystis*, and because *Microcystis* is the cyanobacteria genera of greatest concern in the Delta, it was appropriate for the CWF EIR/EIS to focus on assessing the harmful algae genera *Microcystis*.

#### 4.1.3 Spring as an Important Bloom Period

Mr. Ringelberg claims in his written testimony that spring is now an important period for blooms. He states, “Moreover, because of the current drought conditions, spring is now an important period for bloom formation. (SJC-048 Glibert et al. 2014)” [Exhibit SJC-004, pg. 4, Ln. 9–11]. Mr. Ringelberg used incorrect information to support this statement by using the

Glibert et al. (2014) paper, which refers to diatoms and green algae and does not mention cyanobacteria occurring during spring months. Mr. Rinbelberg admitted on cross examination that the Glibert et al. (2014) did not refer to cyanobacteria. “MS. ANSLEY: And isn't it true that the bloom observed in 2014 was, depending on location, dominated by chlorophytes and diatoms but not microcystis; is that correct? WITNESS RINGELBERG: (Nodding head.)” [Transcript vol. 29, pg. 102, Ln. 5–9]. Mr. Ringelberg goes on to explain in his oral testimony that he used the Glibert et al. (2014) paper to illustrate that the bloom formation was novel. Mr. Ringelberg states: “The intent of the study was not a synoptic study to identify algal blooms, it was to look at algal blooms that they were able to identify in the field recon and provide samples of those.” [Transcript vol. 29, pg. 103, Ln. 10-13].” Glibert et al. (2014) used cell counts to identify a variety of phytoplankton species, but did not mention a single cyanobacteria species. Instead, the paper highlights the positive aspects of the dominant spring diatom and green algae bloom by highlighting the importance of community composition. Specifically, results from the research suggest the importance of diatoms and green algae to the Delta food-web, particularly delta smelt prey items. In comparison, cyanobacteria have poor nutritional value and are not beneficial to the food web. Thus, Mr. Ringelberg is incorrect to assume that the presence of a spring phytoplankton bloom is correlated to being an important period for cyanobacteria formation.

Compared with other phytoplankton genera, cyanobacteria have lower growth rates in colder temperatures. In the Delta, *Microcystis* blooms are generally restricted to summer months between June and November when water temperatures are greater than 19°C (Lehman et al. 2013). Although other factors (nutrients, surface irradiance) generally become sufficient for *Microcystis* growth between March and June, water temperature is generally the limiting factor that prevents *Microcystis* formation in the Delta until water temperatures exceed 19°C, which typically does not happen until June (Lehman et al. 2013). Although water temperature during the spring months is often too cold to support *Microcystis* or other cyanobacteria (e.g., *Aphanizomenon* and *Anabaena*) blooms (Msagati et al. 2006 as cited in Mioni et al. 2012, Berg and Sutula 2015), in the extreme drought year of 2014, elevated spring water temperatures in the Delta extended the *Microcystis* bloom by at least two months in the spring and another two months in the fall. This resulted in an increased duration (eight months) of the *Microcystis* bloom, twice as long as previous bloom seasons (Lehman et al. 2017). This information suggests blooms can form in spring months under severe droughts and when water temperatures are sufficiently high in the spring months, but spring blooms of *Microcystis* have historically been rare in the Delta. The CWF will not result in extreme drought-like conditions in the Delta, relative to the NAA [see also Exhibits DWR-514; DWR-86], and thus spring cyanobacteria blooms are not expected to occur as a result of the CWF.

## 4.2 RIVER FLOWS AND VELOCITY EFFECTS OF THE CWF

Mr. Ringelberg claims the CWF would increase harmful algae blooms in the Delta due to decreased flows. He states: “The proposed project influences flow and water quality within Sacramento San Joaquin Delta as a result of this diversion, and those factors further influence the formation of Harmful Algal Blooms (“HABs” or cyanoHABs).” [Exhibit SJC-004, pg. 1, Ln 24–27]. Mr. Ringelberg provides only unsubstantiated claims and he completed no analysis of



how the CWF would alter flows at specific locations, or how such flow changes would influence the formation of HABs, based on the scientific literature.

Mr. Ringelberg, Mr. Burke, and Mr. Lee claim the CWF would increase harmful algae blooms in Discovery Bay due to decreased flows, diversions and/or reductions of flows from the Sacramento River. Mr. Ringelberg states: “*The Petition completely fails to identify or analyze the potential for the project to create or to exacerbate impacts to human health and the environment from blue-green algae (cyanobacteria) and their toxins, within Discovery Bay.*” [Exhibit SCDA\_33, pg. 2, Ln. 1–3]. He also states: “*Although not addressed at all in the Petition (DWR 1-3) the project is likely to create localized flow conditions that are likely to significantly exacerbate algal and aquatic weed growth. Toxic (and non-toxic) aquatic invasive plants can lead to many potential environmental problems created by the project both in the near-term and cumulatively. Reducing the flow of Sacramento River water through the Delta and concentrating the drainage of the San Joaquin River affects the dilution and the mixing of nutrients.*” [Exhibit SCDA\_33, pg. 2, Ln. 9–14].

Mr. Burke states: “*If diversions are shifted to the proposed NDD, this dilution effect will be reduced or eliminated. This will result in a higher nutrient loads for waters in and around Discovery Bay. All things being equal, higher nutrient loads can lead to algal blooms which reduce dissolved oxygen and lead to degradation of water quality.*” [Exhibit SCDA-35, pg. 2, Ln. 22–25].

Mr. Lee states: “*The proposed WaterFix project’s diversion of Sacramento River water will reduce the amount of Sacramento River water that enters the Central Delta and thereby impact the phosphorus input to the Central Delta and the phytoplankton population in that area of the Delta. The reduction in dilution of phosphorus concentration in the Central Delta leads to impaired water quality and adverse impacts/injuries to the public/users of Central Delta waters.*” [Exhibit CSPA-6-Revised, pg. 17].

See also Mr. Stroshane [RTD 10-Rev 2] generally stating that increased residence time would increase *Microcystis* blooms.

Mr. Ringelberg, Mr. Burke, Mr. Lee and Mr. Shroshane did not provide any evidence to support their claims that the CWF would decrease flows and associated channel velocity and thus turbulence and mixing, and increase residence time, in the Delta. Likewise, Mr. Ringelberg, Mr. Burke and Mr. Lee did not provide any evidence to support their claim that the CWF would increase nutrients in the Discovery Bay area by magnitudes that would affect *Microcystis* blooms. Consequently, their claims are speculative and unsupported. To rebut such unsubstantiated claims, the following analysis is provided.<sup>1</sup>

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<sup>1</sup> For a response to Mr. Ringelberg, Mr. Burke and Mr. Lee’s comments regarding nutrients, see Section 4.6 of this report.

***Based on the nine Delta locations assessed below with regards to daily maximum and absolute 15-minute channel velocities (regardless of direction of flow), modeling shows that the CWF would not substantially increase the frequency with which low channel velocities would occur, relative to the NAA. Consequently, the CWF will not create hydrodynamic conditions that would be substantially more conducive to the occurrence of Microcystis blooms in the Delta relative to the NAA.***

Flow (measured in cubic feet per second (cfs)) is a measure of the volume of water passing a specified location within a channel, whereas velocity (measured in feet per second (ft/s)) is the measure of how rapidly the water is moving within a channel. Channel velocity is the primary driver of channel turbulence and mixing, in-channel generated turbidity, and hydraulic residence time – all of which can affect cyanoHABs. If a channel is large and has substantial cross-sectional area, the channel may have a relatively high flow (cfs) despite having a relatively low velocity (ft/s). Conversely, if a channel has a small cross-sectional area, it may have a relatively low flow (cfs), but a relatively high velocity (ft/s). The distinction between flow and velocity is important when evaluating cyanobacteria because it is not the volume of water moving through a channel, but rather the velocity with which the water moves that most affects the ability of cyanobacteria to out-compete other algae, as discussed further below. Consequently, this assessment compared modeled channel velocity for the CWF and NAA scenarios to determine the hydrodynamic effects of the CWF on cyanoHABs in the Delta, with an emphasis on *Microcystis* blooms.

In calm waters, *Microcystis* cells can move to the water surface through the control of their buoyancy via gas vesicles within the cells (Reynolds 2006). Cells come together to form colonies and then colonies join together to form mats or “scum” layers at the water’s surface. Here, the dense mats of *Microcystis* shade-out the other algal species and thus out-compete the other algae for light and nutrients which fuel their bloom. In higher velocity, turbulent waters, this life history strategy is disrupted. Higher velocity, turbulent water mixes all algae throughout the photic zone of the water column and reduces light through turbidity which allows faster growing chlorophytes (green algae) and diatoms to out-compete the slower growing cyanobacteria, including *Microcystis* (Wetzel et al. 2001, Huisman et al. 2004, Li et al. 2013). Because all algae present are mixed from the channel surface to bottom in turbulent flowing water, *Microcystis* cells cannot control their location in the water column and thus cannot as readily, if at all, form the dense collection of cells and colonies at the water’s surface as occurs in calm waters.

As stated in Section 3.1.3, the channel velocity required to disrupt *Microcystis* blooms varies by system, with studies reporting critical velocity rates of 0.1 to 1.3 ft/s (Mitrovic et al. 2003, Zhang et al. 2007, Long et al. 2011 as cited in Zhang et al. 2015, Mitrovic et al. 2011, Li et al. 2013). For example, in the lower Darling River, Australia, velocities above 1.0 ft/s were shown to quickly disrupt an established cyanobacteria bloom (Mitrovic et al. 2011). In the Zhongxin Lake system China, flow velocities of 0.2 to 1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015).

Channel velocity also dictates residence time within a channel reach because velocities dictate the flushing rate for the reach. Hence, to assess the effects of flow changes caused by the CWF on cyanobacteria, this assessment evaluates channel velocity because velocity is the primary driver of channel turbulence and mixing, in-channel generated turbidity, and residence time – all of which can affect cyanobacteria and its ability to produce blooms.

The velocities are from the Delta Simulation Model II (DSM2) modeling that was conducted in support of DWR’s water right petition and case-in-chief for Alternative 4A, operations scenarios 4A-H3 and 4A-H4 (called 4A-H3 and 4A-H4 herein), and Boundary 1 and Boundary 2 scenarios, as well as the No Action Alternative (NAA) scenario.

The analysis presented below focuses on how the CWF would affect daily maximum velocity and 15-minute absolute velocity (regardless of direction) in channels of the Delta. Daily maximum velocity is assessed because the Delta channels are tidal and thus flows are slowed, and can reverse direction in most channels daily, on the tidal cycle. As such, mathematical daily average velocity may approach zero when flows on the tidal cycle move in opposite directions, and thus is not very useful for determining how channel velocity affects cyanobacteria. In such tidally influenced channels, daily maximum velocity and 15-minute absolute velocity (regardless of direction) are the parameters that best characterize the degree of channel mixing that occurs daily. Hence, this analysis determines how the CWF would affect daily maximum and 15-minute absolute velocity, relative to the NAA. Once CWF-driven reductions in channel velocity were determined, the effect that such reductions could have on *Microcystis* blooms in the Delta channels was then determined, based on the scientific literature.

*Microcystis* blooms have historically been observed in the south and central Delta channels where channel velocities can be low and thus more conducive to bloom formation. Based on studies by Lehman et al. 2008, 2013, Mioni et al. 2012 and Spier et al. 2013, the areas of the Delta that have most often experienced substantial blooms of *Microcystis* are in the Central Delta, between Antioch and Mildred Island. In 2012, substantial *Microcystis* blooms were also observed in the Southeast Delta within the Stockton Deepwater Ship Channel (Spier et al. 2013). *Microcystis* abundance decreases moving west from Antioch to Suisun Bay and it is almost non-detectable by Chipps Island (Lehman et al. 2005, 2008, 2010). *Microcystis* abundance also substantially decreases moving north from Antioch. The locations assessed below for velocity were chosen because they represent: 1) key locations where channel velocities may change due to the proposed north Delta diversions, and 2) areas of the Delta (south and central Delta channels) that have historically experienced *Microcystis* blooms.

#### *Sacramento River at Freeport*

At Freeport on the lower Sacramento River, included in this assessment to evaluate river velocities upstream of the proposed north Delta diversions, DSM2 modeling output shows that daily maximum velocity would be above 1.0 ft/s all the time. The frequency with which any given velocity above 1.0 ft/s would be exceeded for the CWF scenarios modeled (i.e., 4A-H3, 4A-H4, BNDY 1 and BNDY 2) would be similar to or greater than that for the NAA (**Figure 1**). Hence, the CWF would not decrease, but rather would often increase, daily maximum velocity at

Freeport, relative to that which would occur for the NAA. Consequently, the CWF would maintain similar or somewhat greater turbulent flow conditions in the lower Sacramento River at Freeport, relative to the NAA, which would not provide more favorable flow conditions for *Microcystis* blooms in the river. In fact, based on the scientific literature cited above and the daily maximum velocities shown in Figure 1, one would not expect cyanobacteria to outcompete diatoms and green algae in the lower Sacramento River at Freeport under the CWF or NAA scenarios. Water temperature and nutrient levels have been adequate to support *Microcystis* in the river near Freeport during the summer, annually, but the river’s velocities, turbulent flow, and turbidity have prevented *Microcystis* blooms from occurring here in the past. This would be expected to continue in the future under the CWF.

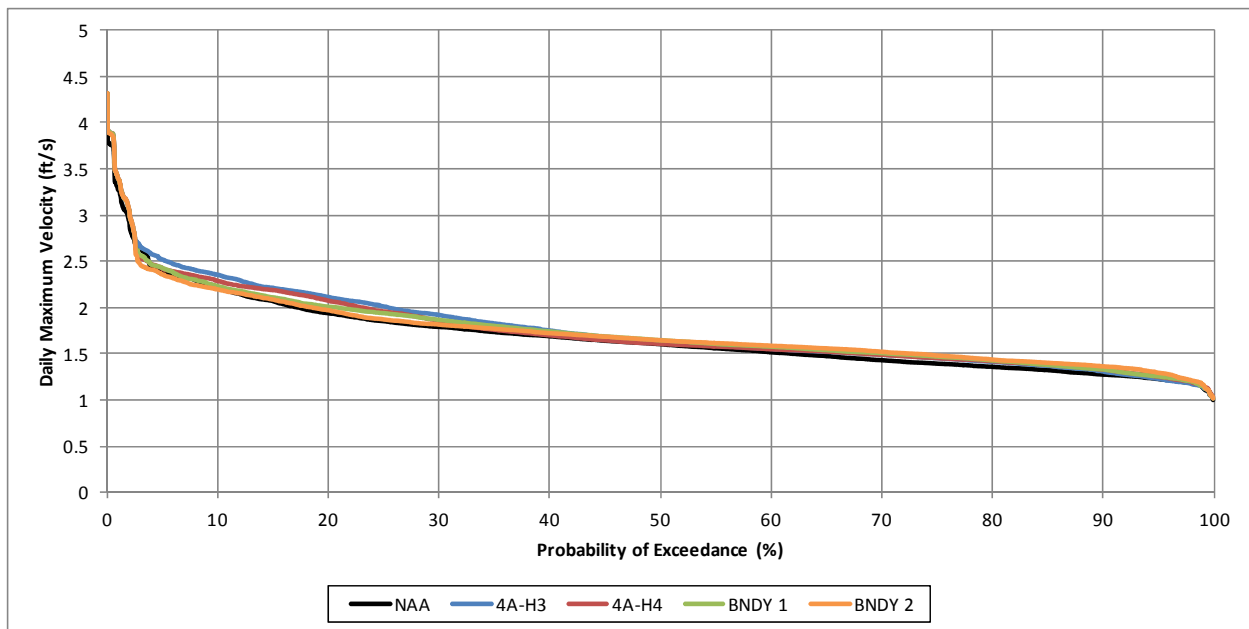


Figure 1. Probability of exceedance of daily maximum velocity in the lower Sacramento River at Freeport for the 1976–1991 period of record modeled.

#### Lower Sacramento River at Rio Vista

The lower Sacramento River at Rio Vista was assessed because it is downstream of the proposed north Delta diversions and Delta Cross Channel located at Walnut Grove, and upstream of the river’s confluence with the San Joaquin River. DSM2 modeling output shows that the frequency with which any given daily maximum velocity would occur in the lower Sacramento River at Rio Vista, downstream of the new north Delta intakes, would be virtually the same for the CWF scenarios, relative to the NAA (Figure 2). The same is true when looking at the absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step at this location during the months June through November (Figure 3). Consequently, from a flow velocity and associated river turbulence, mixing, and residence time perspective, the CWF would not increase the potential for *Microcystis* blooms to occur in the lower Sacramento River, in the vicinity of Rio Vista, relative to that for the NAA.

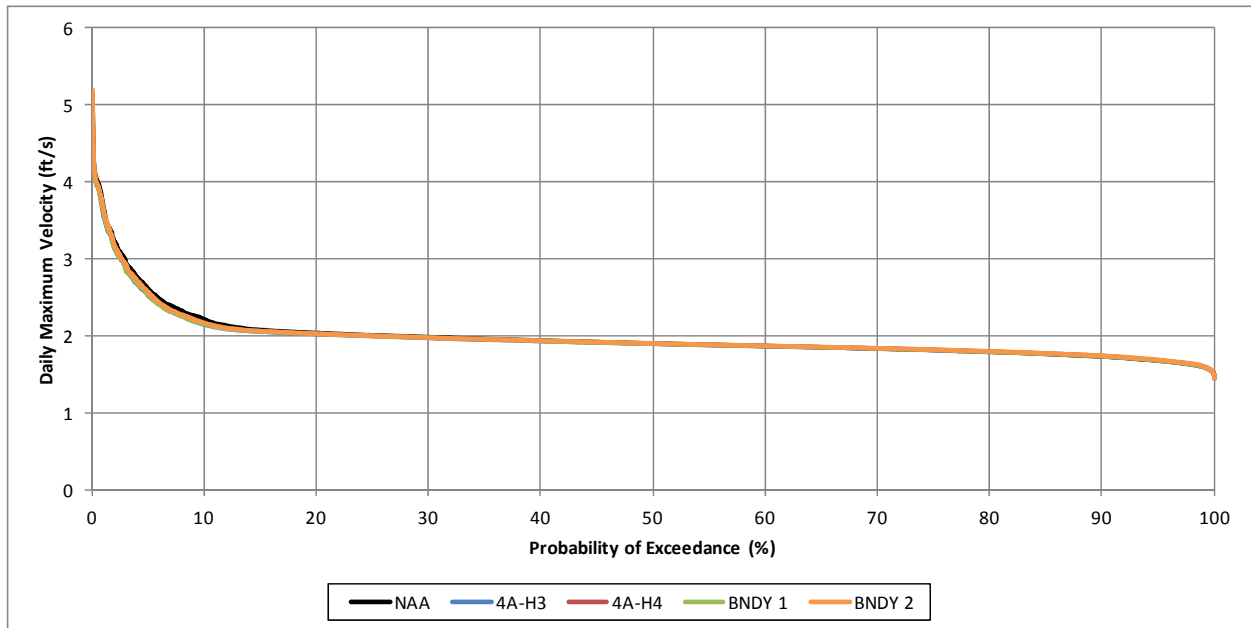


Figure 2. Probability of exceedance of daily maximum velocity in the lower Sacramento River at Rio Vista for the 1976–1991 period of record modeled.

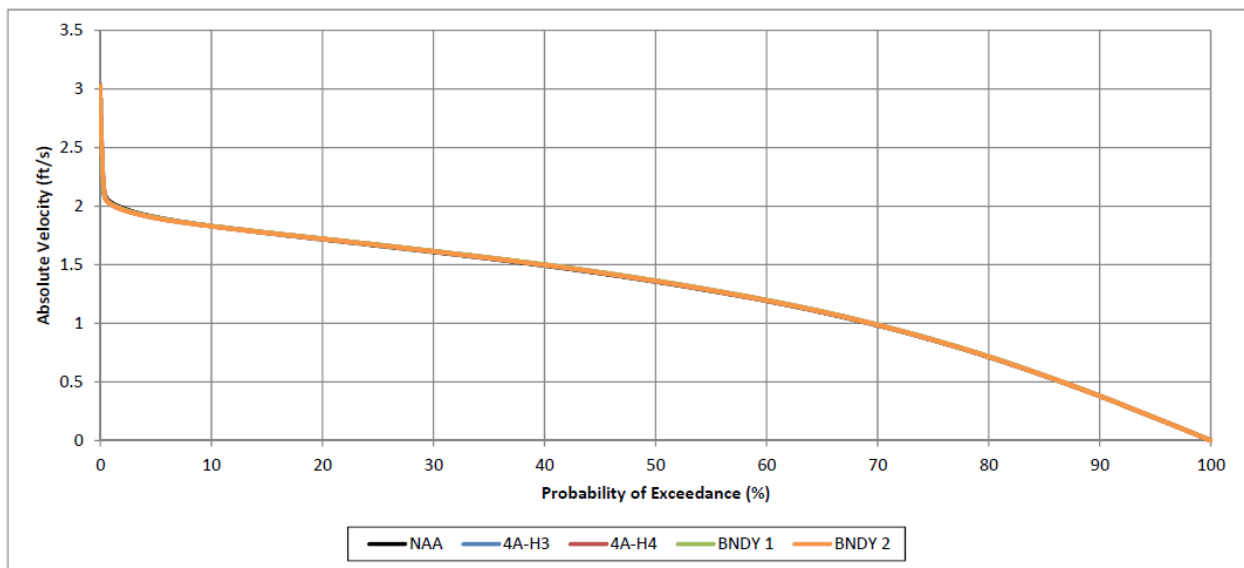


Figure 3. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the lower Sacramento River at Rio Vista during the months June through November for the 1976–1991 period of record modeled.

*San Joaquin River at Brandt Bridge and Antioch*

These locations were selected because they book-end the San Joaquin River, across the central Delta, from east to west. The frequency with which any given daily maximum velocity would be exceeded in the San Joaquin River at Brandt Bridge (**Figure 4**) and Antioch (**Figure 6**) for the CWF scenarios would be the same or greater than that for the NAA. The same is true when looking at the absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step at these locations during the months June through November (**Figure 5** and **Figure 7**). Consequently, the CWF would maintain similar to somewhat greater turbulent flow, mixing, and resident time conditions in the San Joaquin River, relative to the NAA, which would not provide more favorable flow conditions for *Microcystis* blooms in the river. Because velocities above 1.0 ft/s were shown to quickly disrupt an established cyanobacteria bloom (Mitrovic et al. 2011) and flow velocities of 0.2–1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015), because daily maximum velocities at Brandt Bridge and Antioch would always be at or above 1 ft/s based on modeling output, and because the frequency with which any given velocity would occur would be about the same or greater for the CWF, relative to the NAA, at both locations for the months June through November (Figure 5 and Figure 7), one would not expect cyanobacteria to outcompete diatoms and green algae in the San Joaquin River in the vicinity of Brandt Bridge or Antioch under the CWF or NAA scenarios. Based on the similarity in channel velocities between the scenarios, turbulence and mixing and resident time conditions would not be expected to be substantially more favorable for cyanobacteria for the CWF scenarios, relative to the NAA scenario. Hence, the potential for cyanobacteria blooms to occur at these river locations would not be substantially increased by the CWF channel velocities, relative to channel velocities that would occur for the NAA.

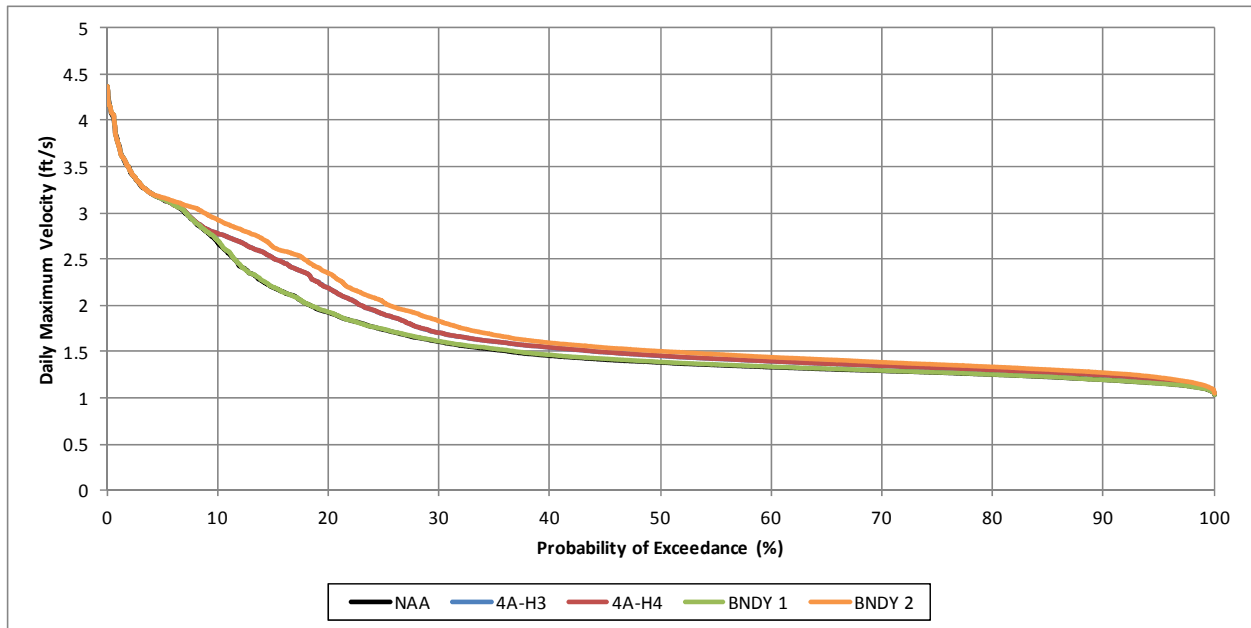


Figure 4. Probability of exceedance of daily maximum velocity in the San Joaquin River at Brandt Bridge for the 1976–1991 period of record modeled.

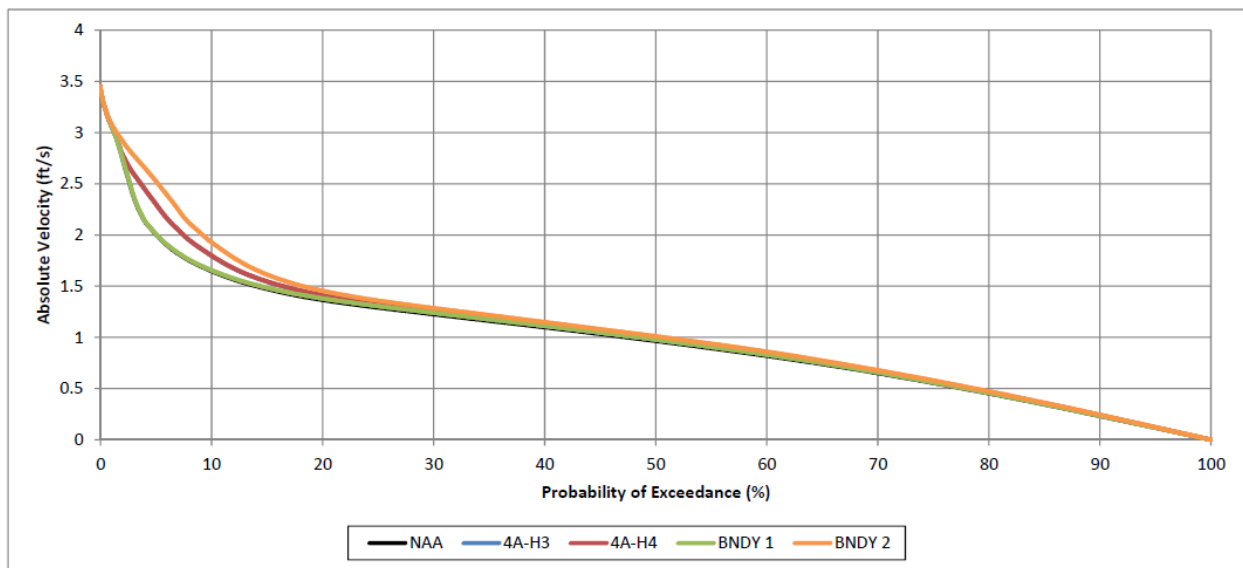


Figure 5. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the San Joaquin River at Brandt Bridge during the months June through November for the 1976–1991 period of record modeled.

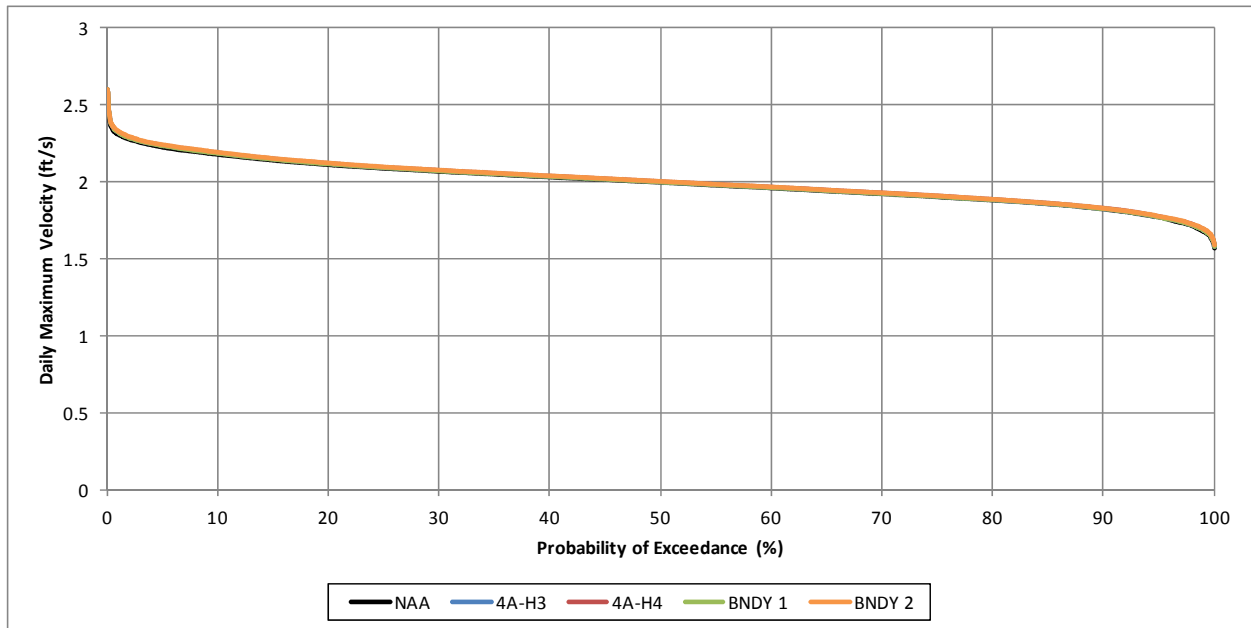


Figure 6. Probability of exceedance of daily maximum velocity in the San Joaquin River at Antioch for the 1976–1991 period of record modeled.

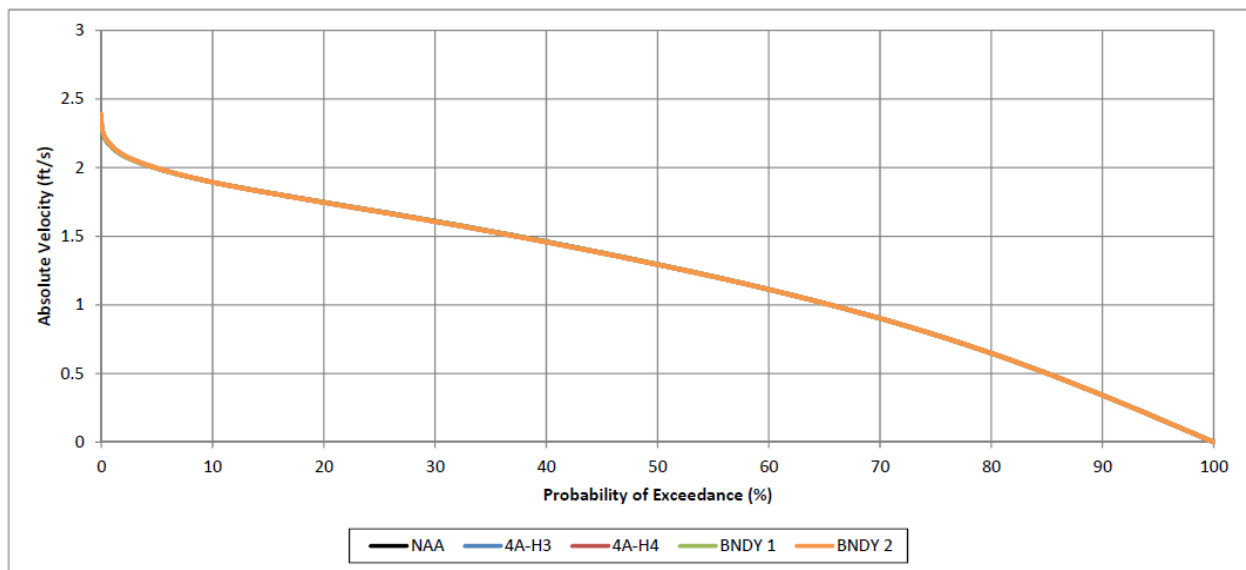


Figure 7. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the San Joaquin River at Antioch during the months June through November for the 1976–1991 period of record modeled.



### *San Joaquin River at Buckley Cove*

Buckley Cove on the San Joaquin River was chosen for assessment because it was a water quality assessment location for Chapter 8 of the EIR/EIS, and because it is within the Stockton Deep Water Ship Channel. In the San Joaquin River at Buckley Cove, daily maximum velocity would be below 1 ft/s about 93% of the time for both the CWF scenarios and the NAA (**Figure 8**). For the 50% of the time when daily maximum velocities would be lowest for this location, the frequency with which any given velocity would be exceeded would be the same for the CWF and the NAA. Likewise, the absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step, would be the same for the CWF as for the NAA during the months June through November (**Figure 9**). The frequency with which absolute channel velocities would be below 0.2 ft/s during these months would be the same for the CWF and the NAA scenarios, which would be about 22% of the time.

Because flow velocities of 0.2–1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015), because daily maximum velocities at Buckley Cove would always be at or above 0.4 ft/s based on modeling output, and because the absolute value of channel velocities on a 15-minute time-step (regardless of flow direction within the channel) would be above 0.2 ft/s about 78% of the time for both the CWF and NAA scenarios, one would not expect cyanobacteria to outcompete diatoms and green algae in the San Joaquin River in the vicinity of Buckley Cove much of the time under the CWF or NAA scenarios. However, there is the potential for *Microcystis* blooms to develop in this reach of the river when all conditions for blooms are met, including low velocities. That said, the CWF would not cause lower daily maximum velocities, or reduce the frequency with which any given velocity would occur when velocities are low during the months June through November, relative to the NAA and thus would not create hydraulic conditions that would be more conducive to *Microcystis* blooms at this location, relative to the NAA.

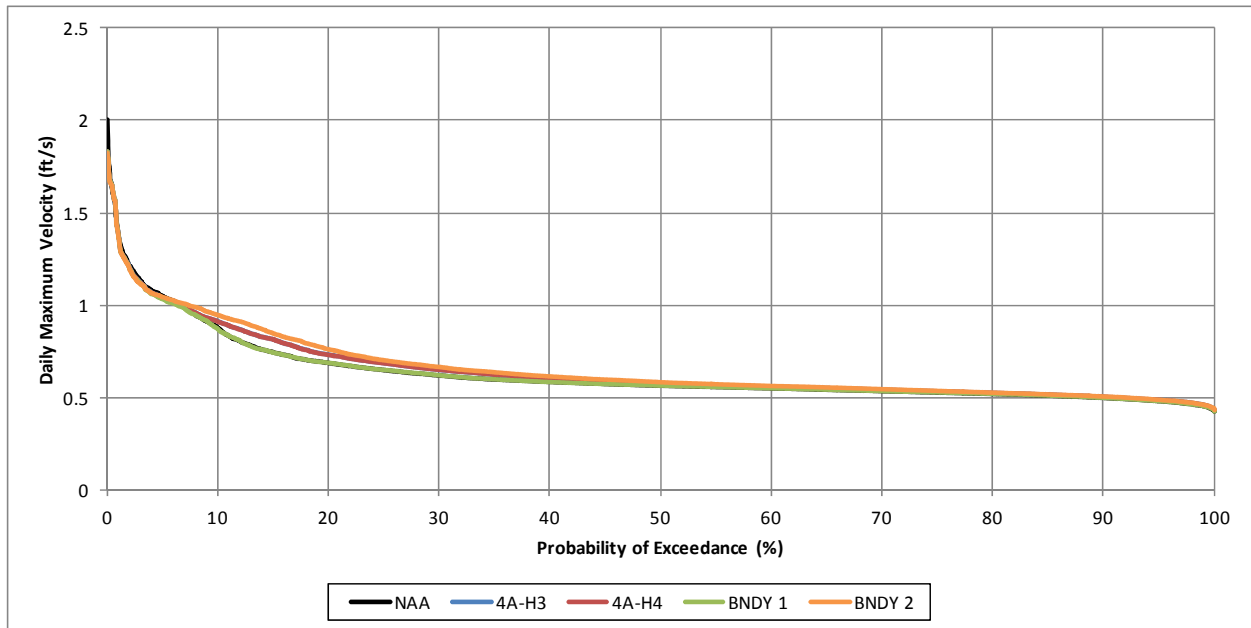


Figure 8. Probability of exceedance of daily maximum velocity in the San Joaquin River at Buckley Cove for the 1976–1991 period of record modeled.

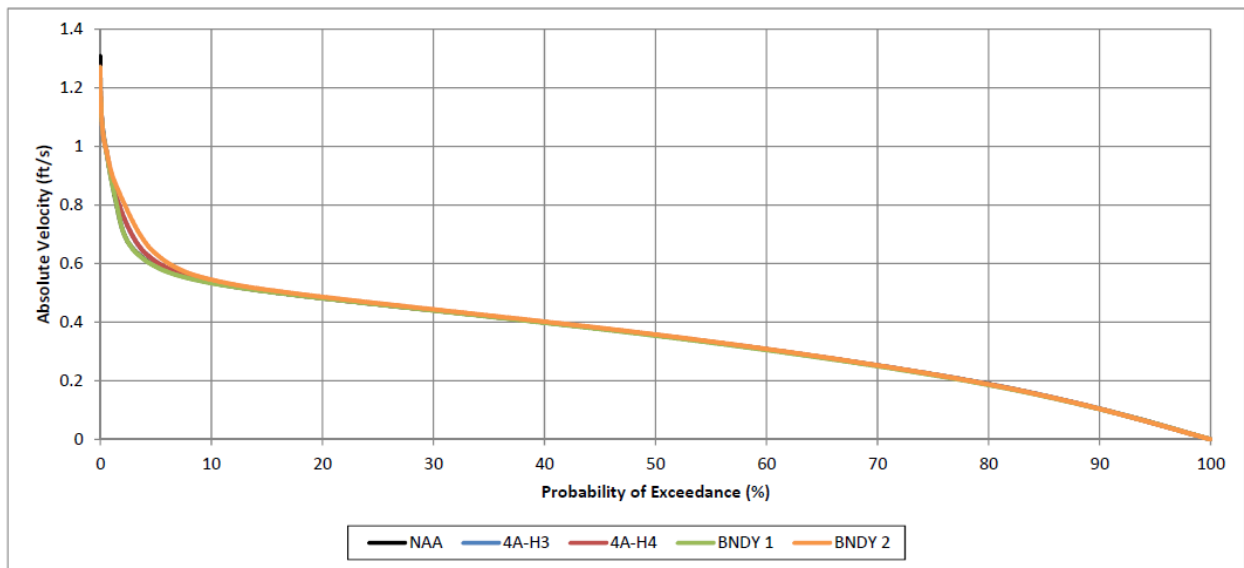


Figure 9. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in the San Joaquin River at Buckley Cove during the months June through November for the 1976–1991 period of record modeled.

### *Old River at Tracy Road*

Old River at Tracy Road was selected to represent a location in the south Delta that may experience *Microcystis* blooms. Looking at Old River at Tracy Road (**Figure 10**), modeling output shows that the frequency with which any given daily maximum velocity would occur for the CWF scenarios would differ negligibly from that modeled for the NAA. Likewise, the absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step, would be the same for the CWF as for the NAA during the months June through November (**Figure 11**).

In Old River at Tracy Road, the frequency with which daily maximum velocity would be at levels less than 0.5 ft/s would be nearly the same for the CWF scenarios and the NAA, and would be identical for the 30% of the time when daily maximum velocities would be the lowest (0.2–0.3 ft/s) at this location. It is at times when daily velocities would be lowest during the summer months that *Microcystis* blooms would be most likely to occur here. Nevertheless, modeling shows that the CWF rarely cause lower daily maximum velocities and would not reduce the frequency with which any given velocity would occur when velocities are below about 0.4 ft/s during the months June through November (Figure 11), and thus would not create hydraulic conditions that would be more conducive to *Microcystis* blooms at this location, relative to the NAA. Although *Microcystis* blooms may occur in Old River near Tracy Road in the future due to its relatively low channel velocities, modeling shows that channel velocities at this location would not be made more conducive to *Microcystis* blooms for the CWF, relative to that which would occur for the NAA.

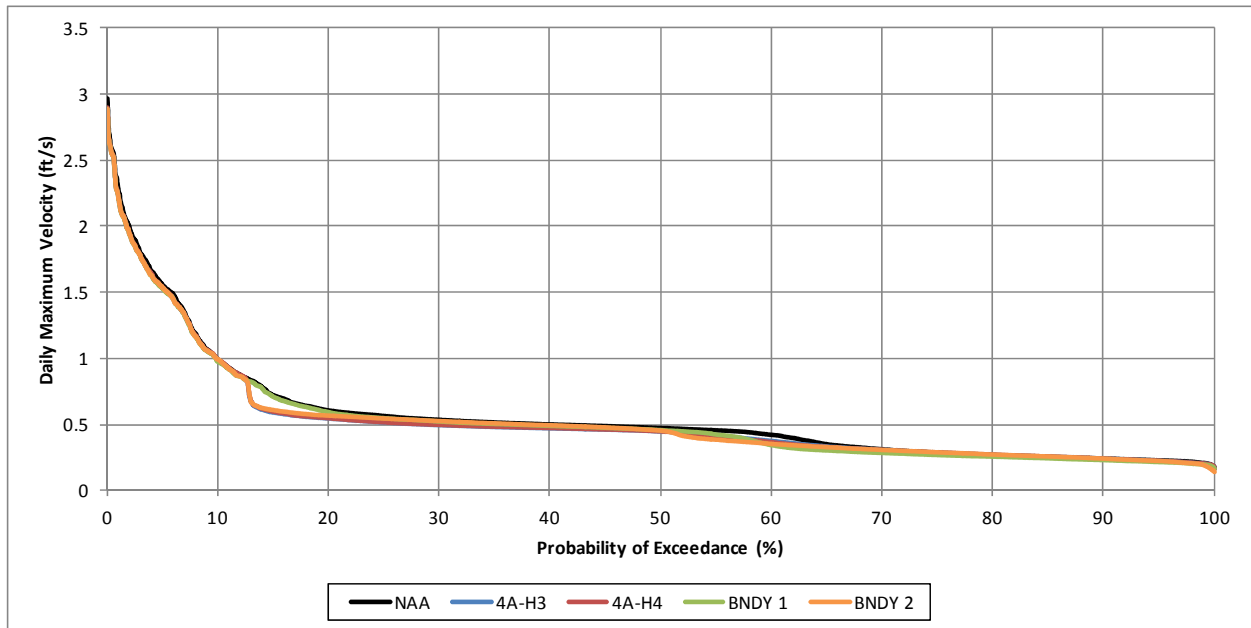


Figure 10. Probability of exceedance of daily maximum velocity in the Old River at Tracy Road for the 1976–1991 period of record modeled.

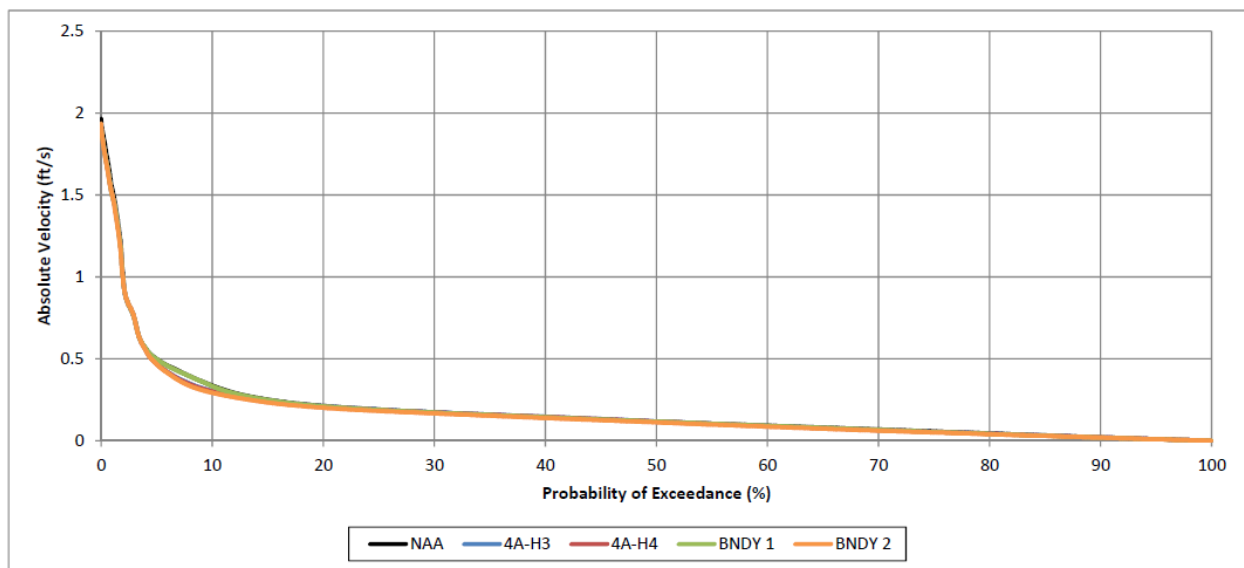


Figure 11. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Old River at Tracy Road during the months June through November for the 1976–1991 period of record modeled.

### *Grant Line Canal*

Grant Line Canal was selected to represent a location in the south Delta that may experience *Microcystis* blooms. Modeling output shows that daily maximum velocities in Grant Line Canal (**Figure 12**) would always remain above 0.5 ft/s for the CWF scenarios and the NAA. Although the frequency that any given daily maximum velocity above 1.25 ft/s would be exceeded for the CWF would be somewhat less than for the NAA, *Microcystis* blooms are not expected to occur when daily maximum channel velocities are above 1.25 ft/s. For the 40% of the time when daily maximum velocity is the lowest at this location (i.e., below 1 ft/s), the frequency of exceeding any given velocity would be the same for the CWF and the NAA.

Likewise, the frequency with which any given absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step, would occur would be about the same for the CWF as for the NAA in Grant line Canal during the months June through November. The frequency with which absolute channel velocities would be below 0.2 ft/s during these months would be somewhat lesser for the CWF than for the NAA (**Figure 13**).

Because flow velocities of 0.2–1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015), and because daily maximum velocities at Grant Line Canal would always be at or above 0.6 ft/s based on modeling output (Figure 12), one would not expect cyanobacteria to outcompete diatoms and green algae in Grant Line Canal much of the time under the CWF or NAA scenarios. However, there is some chance that *Microcystis* blooms could develop in the canal when all conditions for blooms are met, including low daily velocities. That said, the CWF would have minimal effects on maximum daily velocities and would not reduce the frequency with which any given velocity would occur during the months June through November, relative to the NAA and thus would not create hydraulic conditions that would be more conducive to *Microcystis* blooms at this location, relative to the NAA. Hence, the frequency with which *Microcystis* blooms could form in Grant Line Canal, with regards to hydraulic conditions, would not be greater for the CWF than for the NAA.

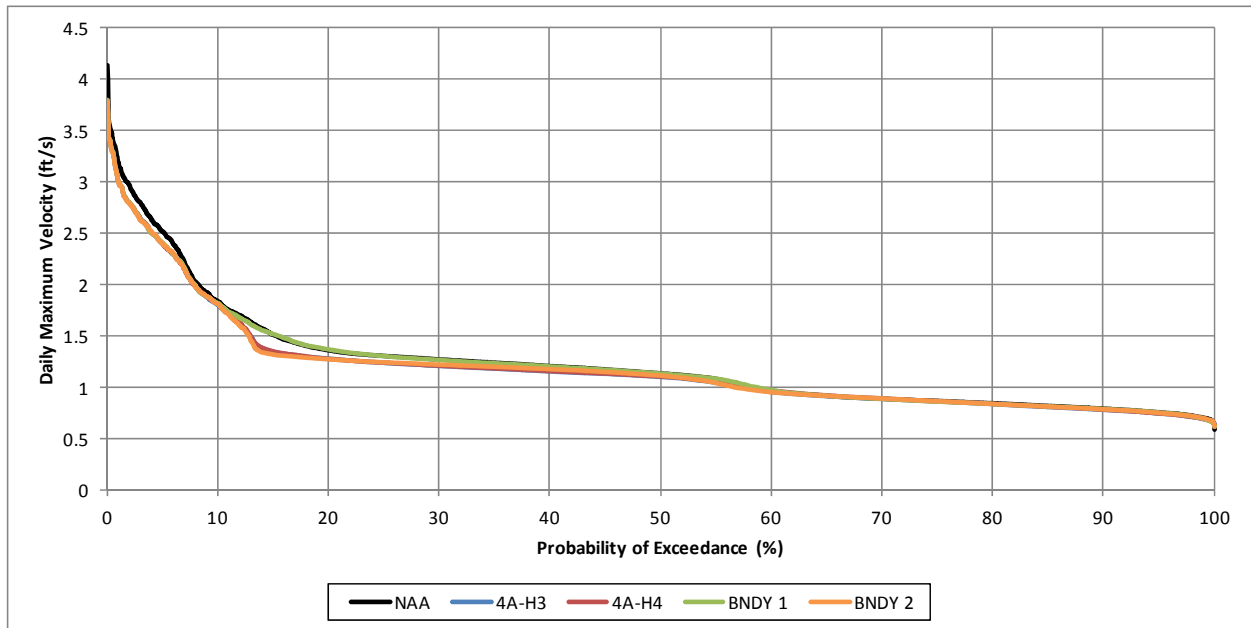


Figure 12. Probability of exceedance of daily maximum velocity in the Grant Line Canal for the 1976–1991 period of record modeled.

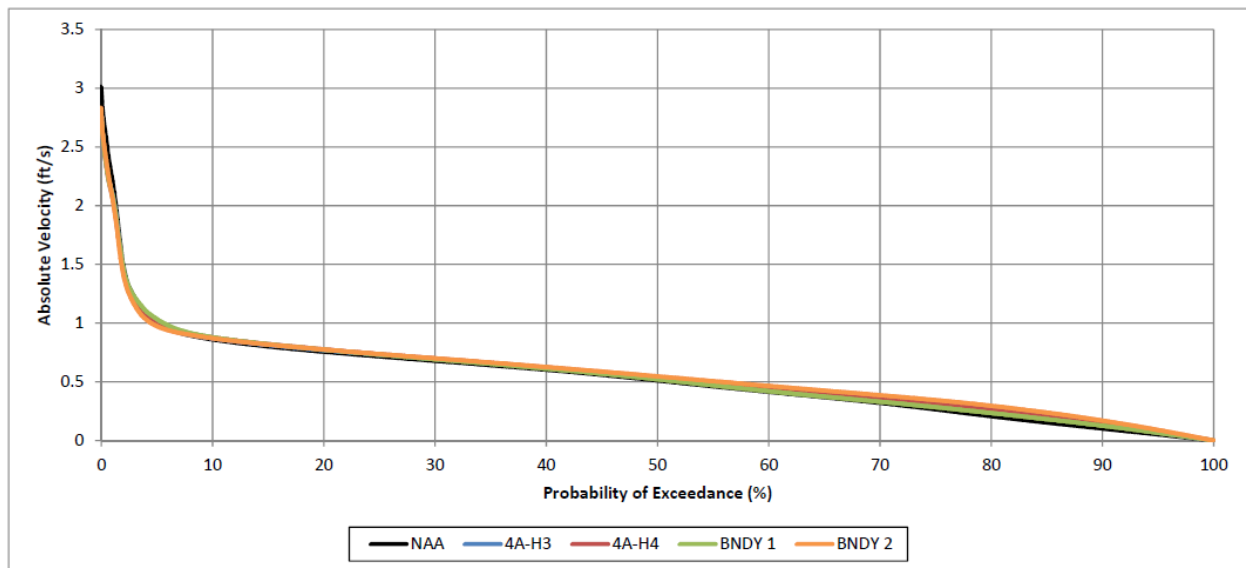


Figure 13. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Grant Line Canal during the months June through November for the 1976–1991 period of record modeled.

### *Middle River at Bacon Island*

Middle River at Bacon Island was selected to represent a location within Middle River and the central Delta that may experience *Microcystis* blooms. Modeling output shows that daily maximum velocities in Middle River at Bacon Island would nearly always remain above 0.6 ft/s for the CWF scenarios and the NAA. Daily maximum velocity would exceed 0.8 ft/s about 70% of the time for the CWF and about 80% of the time for the NAA. The frequency with which any given daily maximum velocity above 0.6 ft/s would be exceeded for the CWF would be somewhat less than for the NAA (**Figure 14**).

The frequency with which any given absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step, would occur would be similar or greater for the CWF, relative to the NAA, when velocities are about 0.5 ft/s or lower during the months June through November. The frequency with which absolute velocities would exceed 0.5 ft/s, as modeled on a on a 15-minute time-step, would be somewhat lower for the CWF during these months, relative to the NAA (**Figure 15**).

Because flow velocities of 0.2–1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015), because daily maximum velocities in Middle River at Bacon Island would nearly always be at or above 0.6 ft/s based on modeling output (Figure 14), and because the frequency with which any given absolute value of channel velocities (regardless of direction) would occur would be similar or greater for the CWF, relative to the NAA, when velocities are about 0.5 ft/s or lower, cyanobacteria would not be expected to outcompete diatoms and green algae at this location much of the time for either the CWF or NAA scenarios. However, there is some chance that *Microcystis* blooms would develop in the river when all conditions for blooms are met, including low daily velocities. That said, the CWF would not cause more frequent occurrence of velocities below about 0.5 ft/s and thus would not create hydraulic conditions that would be substantially more conducive to *Microcystis* blooms at this location, relative to the NAA.

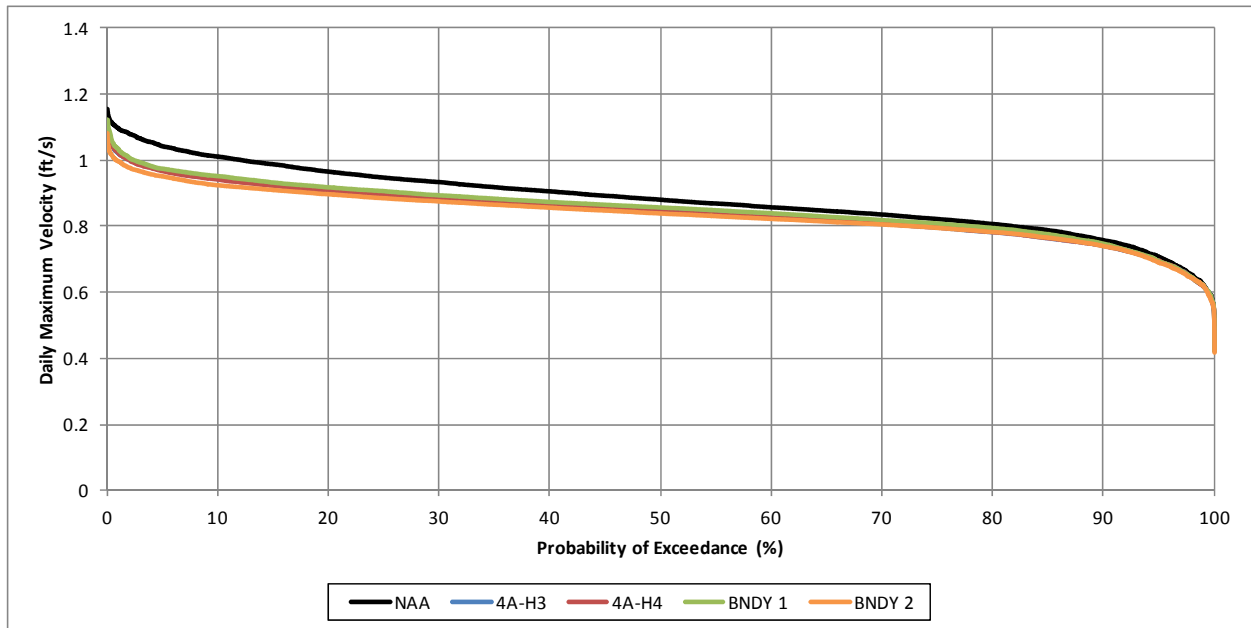


Figure 14. Probability of exceedance of daily maximum velocity in the Middle River at Bacon Island for the 1976–1991 period of record modeled.

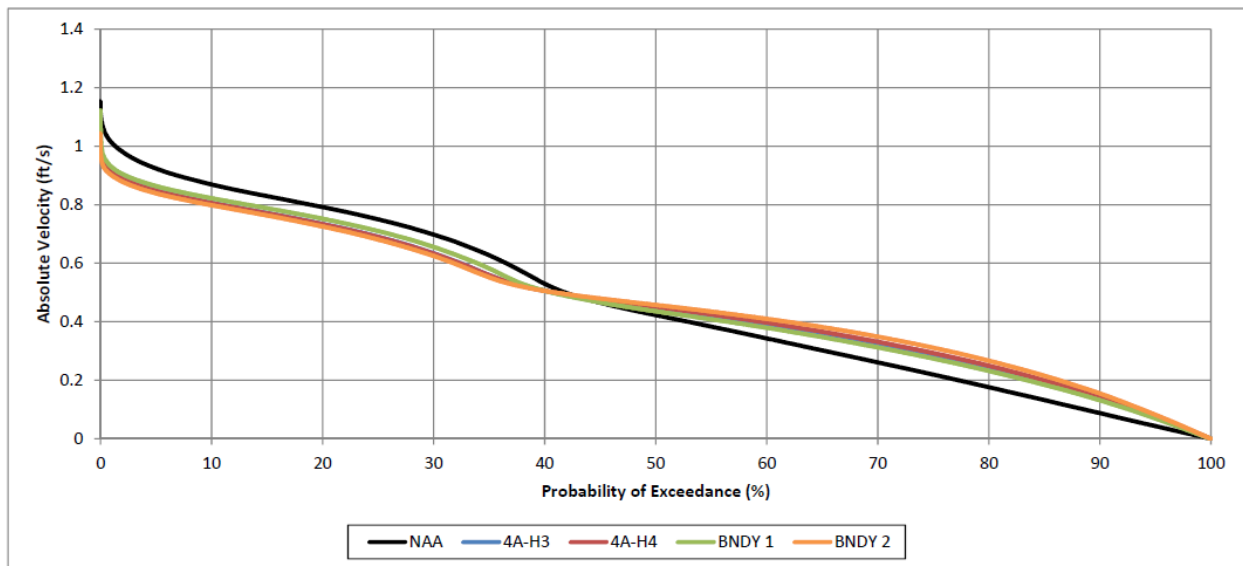


Figure 15. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Middle River at Bacon Island during the months June through November for the 1976–1991 period of record modeled.



### *Old River at Rock Slough*

Old River at Rock Slough was selected to represent a location within Old River and the central Delta that may experience *Microcystis* blooms, and because it is a main river channel that provides flow to the Discovery Bay area. Modeling output shows that daily maximum velocities in Old River at Rock Slough would nearly always remain above 0.8 ft/s for the CWF scenarios and the NAA. Although the frequency with which any given daily maximum velocity above 1.0 ft/s for the CWF would be somewhat less than for the NAA, *Microcystis* blooms are not expected to occur when daily maximum channel velocities are above 1.0 ft/s. For the 40% of the time when daily maximum velocity is the lowest at this location (i.e., below 1 ft/s), the frequency of exceeding any given velocity would be nearly the same for the CWF and the NAA.

The frequency with which any given absolute value of channel velocities (regardless of direction), as modeled by DSM2 on a 15-minute time-step, would occur would be similar or greater for the CWF, relative to the NAA, when velocities are about 0.8 ft/s or lower during the months June through November. The frequency with which absolute velocities would exceed 0.8 ft/s, as modeled on a on a 15-minute time-step, would be similar or somewhat lower for the CWF during these months, relative to the NAA (Figure 17).

Because flow velocities of 0.2–1.0 ft/s disrupted *Microcystis* blooms and shifted the dominant phytoplankton species to green algae and diatoms (Li et al. 2013, Zhang et al. 2015), and because daily maximum velocities in Old River at Rock Slough would always be at or above 0.8 ft/s based on modeling output (Figure 16), one would not expect cyanobacteria to outcompete diatoms and green algae in Old River at Rock Slough most of the time under the CWF or NAA scenarios. However, there is some chance that *Microcystis* blooms could develop in the channel when all conditions for blooms are met, including low daily maximum velocities. That said, the CWF would have little effect on daily maximum velocities and would either have no effect or increase the frequency with which velocities below 0.8 ft/s would occur and thus would not create hydraulic conditions that would be more conducive to *Microcystis* blooms at this location, relative to the NAA.

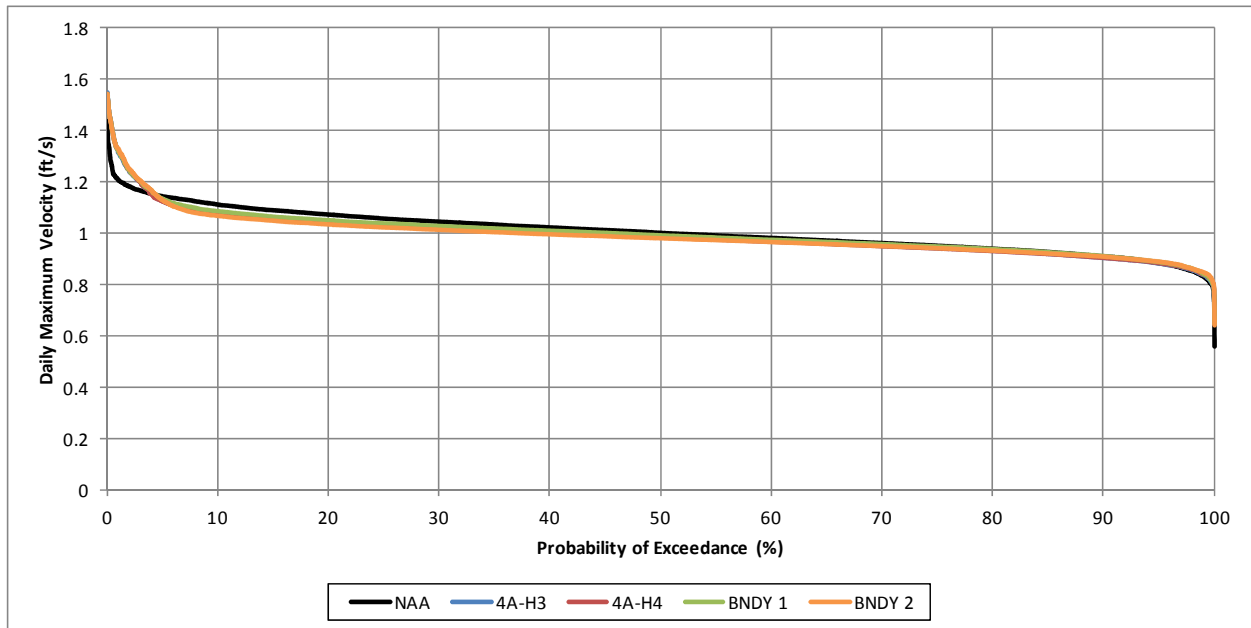


Figure 16. Probability of exceedance of daily maximum velocity in the Old River at Rock Slough for the 1976–1991 period of record modeled.

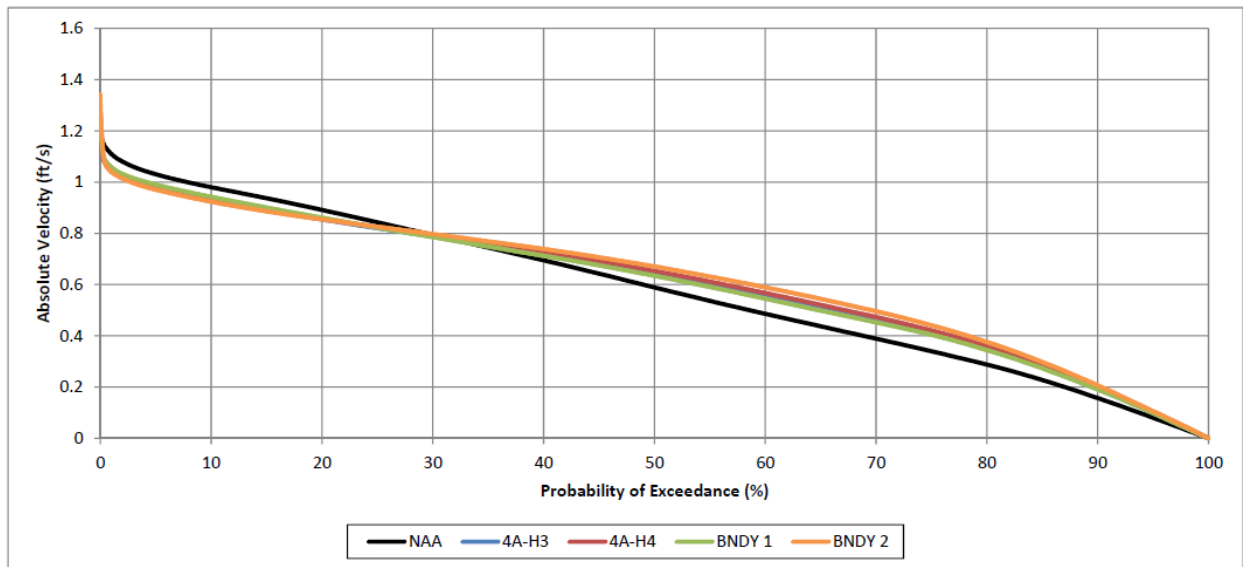


Figure 17. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Old River at Rock Slough during the months June through November for the 1976–1991 period of record modeled.

#### *Old River at Highway 4*

Old River at Hwy 4 was selected to represent a location within Old River and the south Delta that may experience *Microcystis* blooms, and because it is just south of Discovery Bay and thus serves as a second location, along with Old River at Rock Slough, to address Mr. Ringelberg, Mr. Burke, and Mr. Lee's claims that the CWF would exacerbate cyanobacteria blooms within Discovery Bay. Old River is a primary river channel providing water to the Discovery Bay area. Modeled velocity data were not available for locations closer to or within Discovery Bay.

As shown in **Figure 18**, the frequency with which any given maximum daily channel velocity below 2.0 ft/s would be exceeded would be lower for the CWF, relative to the NAA. The frequency that velocities above 2.0 ft/s would occur at this location for the CWF would be similar or higher than that for the NAA. Maximum daily channel velocities would remain at or above 1 ft/s about 98% of the time for the CWF compared to nearly 100% of the time for the NAA. These modeled daily maximum velocity data indicate that the site would experience sufficiently high velocities, on a daily time-step, to maintain a well mixed channel, and to prevent extended periods (i.e., many days or weeks) with little to no water movement.

The frequency with which absolute channel velocities (in either direction) would exceed about 0.75 ft/s would be lower for the CWF, relative to the NAA. Conversely, the frequency with which absolute channel velocities would exceed levels between zero and 0.75 ft/s would be the same or greater for the CWF, relative to the NAA. Hence, for the 50% of the time when Old River channel velocities at Hwy 4 are at their lowest, the CWF would typically have channel velocities equal to or slightly greater than those for the NAA.

Because daily maximum channel velocities would be maintained at or above about 1.0 ft/s for both the CWF and NAA scenarios, and because for the 50% of the time when Old River channel velocities at Hwy 4 are at their lowest, the CWF would typically have channel velocities equal to or slightly greater than those for the NAA, I would not expect the channel velocities modeled to occur for this location for the CWF to cause an increase in the frequency that *Microcystis* blooms occur here.

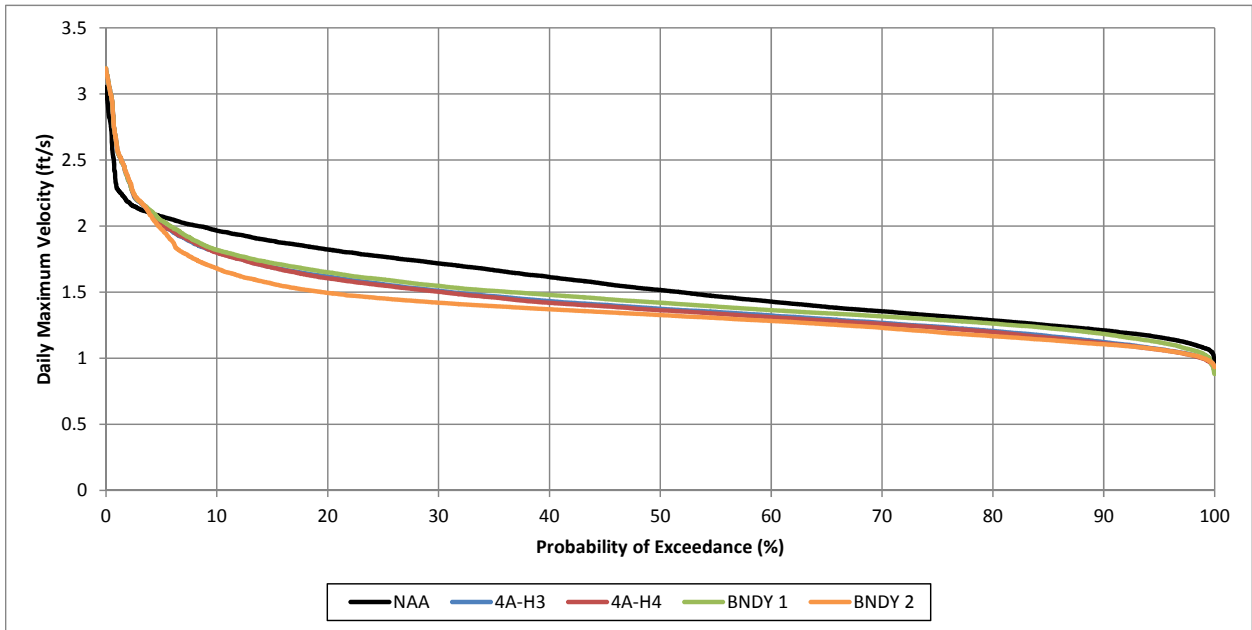


Figure 18. Probability of exceedance of daily maximum velocity in Old River at Hwy 4 for the 1976–1991 period of record modeled.

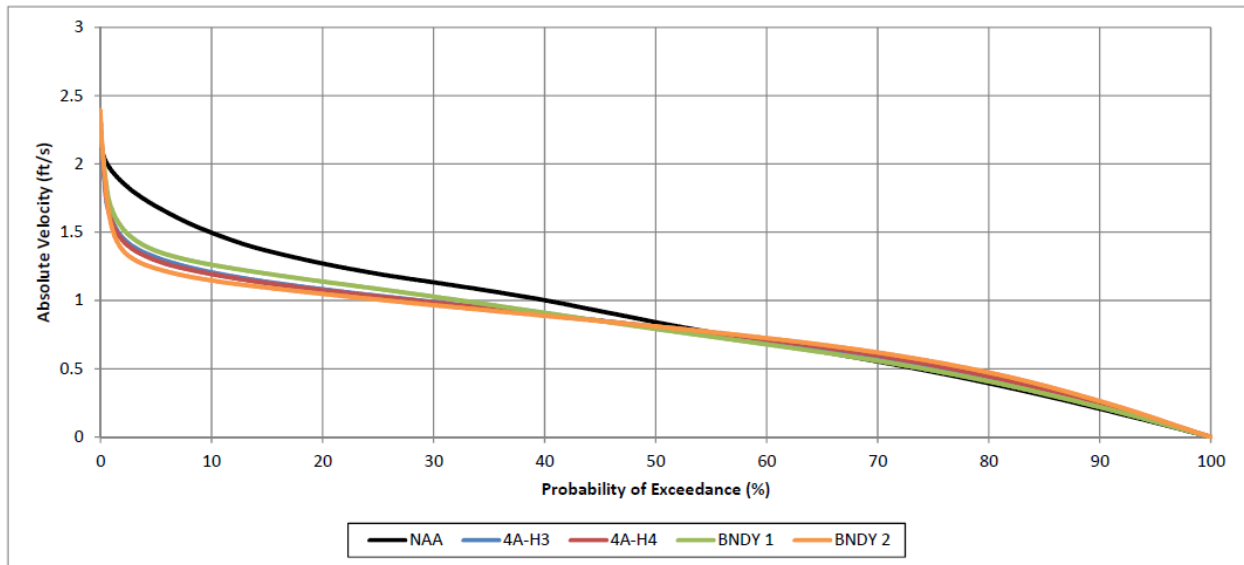


Figure 19. Probability of exceedance of absolute values of daily velocities, on a 15-minute time-step, in Old River at Hwy 4 during the months June through November for the 1976–1991 period of record modeled.

### 4.3 RESIDENCE TIME EFFECTS OF THE CWF

Mr. Burke and Mr. Ringelberg claim the CWF would increase residence time in the Delta thereby allowing cyanobacteria to increase. Mr. Burke states: “A decrease in the volume of water that is flushed through the system can result in a buildup of nutrients, increased water temperatures, and an increase in algal growth.” [Exhibit-SDWA—76 ERRATA, paragraph 16, Ln. 10-12]. Mr. Ringelberg states: “If the conveyance facility is built, the north-to-south draw of water across the delta that has existed for decades would likely be reduced as a result of compensatory reductions in pumping from the south delta, creating much longer average residence times. Longer residence times are associated with higher rates of algal growth, which could fuel eutrophication in some regions, including increased blooms of nuisance algae, such as *Microcystis*, which is toxic to humans and other organisms (Lehman and others, 2013).” [Exhibit SJC-004, pg. 12, Ln. 9-15]. Further Mr. Ringelberg states: “Removing significant fractions of the flow of the Sacramento River and concentrating that effect in a river corridor profoundly changes the downstream channel flow (velocity). The flow-related dilution and water column mixing, as well as the induction of flow reversals which serve to lengthen residence time, are further exacerbating conditions that lead to HAB formation and maintenance.” [Exhibit SJC-004, pg. 14, Ln. 19-23].

Mr. Burke provided insufficient information and Mr. Ringelberg did not provide any evidence to support their respective claims that residence times will increase due to the CWF, and thus the frequency and magnitude of cyanoHABs will be made worse by increased residence times. As such, their claims are either largely or completely unsupported.

***Hydraulic residence times may increase in parts of the southern and central Delta for the CWF, relative to the NAA. Increased residence time provides the opportunity for cyanobacteria to accumulate in areas. However, other factors such as daily in-channel absolute velocities, turbulence, and mixing; competition with other algal species; and grazing losses to zooplankton, fish, and clams exert their own effects on cyanobacteria accumulation, and thus a given magnitude increase in residence time will not always equate to a given magnitude increase in bloom size, or an increase in bloom size at all. Because of the many factors involved beyond residence time alone, relationships between bloom size and residence time are expected to be highly variable both spatially and temporally in the Delta. Additional *Microcystis* research would be needed before definitive determinations regarding how modeled changes in residence time caused by the CWF would affect the magnitude of *Microcystis* blooms in the Delta can be made.***

The current science on *Microcystis* in the Delta indicates that factors such as water temperature, channel velocity and turbulence, irradiance, nutrient availability primarily dictate whether *Microcystis* can out-compete other algae for available resources and produce a bloom at a given location. Because *Microcystis* is relatively slow growing compared to other algal species, sufficient residence time (due to low channel velocities) is needed to enable a bloom to become established. Insufficient residence time (due to high channel velocities) results in what cells are produced being flushed from the area before a “bloom” can form, and high velocities result in turbulent, well mixed channel flows where cyanobacteria generally cannot out-compete green

algae or diatoms. Hence residence times beyond the minimum required for bloom initiation (e.g., increased residence times in areas where blooms have historically occurred) primarily affects how much biomass a bloom can accumulate in an area after a bloom has initiated.

Long residence time does not always translate into large *Microcystis* blooms. This was exemplified in the Stockton Deep Water Ship Channel, where long summer residence times occur annually. Here, a three year study documented a large persistent *Microcystis* bloom in 2012 but not in 2009 or 2011 (Spier et al. 2013). Environmental conditions were similar in 2012 and 2009 and *Microcystis* cells were present in 2009, yet no large bloom occurred in 2009. No specific environmental factor could be attributed to the 2012 bloom (Spier et al. 2013). This suggests *Microcystis* ecology and competition with other algae is complex, and longer residence times do not necessarily indicate that a bloom will form.

When considering how any given residence time (modeled in days) or increase in residence time may affect *Microcystis* bloom formation and persistence, it is also important to distinguish between areas that have higher residence times because they are truly lake-like with little water movement (e.g., a back-water slough) versus those more tidally influenced where a particle may move long distances upstream on the flood tide and long distances back downstream on the ebb tide. Two such environments could have nearly the same estimated hydraulic residence times. For the former example, channel velocities and turbulence would be low and water column stability high. In the latter example, daily channel velocities and turbulence would be relatively high and thus water column stability low. Hydrodynamic conditions would be more favorable to *Microcystis* in the former, versus the latter example, despite the fact that their estimated residence times may be nearly the same.

Lehman et al. (2017) states that high residence time was a factor that contributed to the magnitude of the 2014 *Microcystis* bloom in the Delta. The high residence time allows *Microcystis* colonies to accumulate in areas of the Delta, without getting flushed from the area. There is no evidence in the scientific literature to indicate that higher residence time result in higher algal growth rates, as claimed by Mr. Ringelberg. Algal species, availability of nutrients, and temperature primarily control algal growth rates, not residence time *per se*. Accumulation of *Microcystis* cells and colonies (via longer residence times) is an important mechanism affecting controlling the magnitude of *Microcystis* blooms, because *Microcystis* has a slow growth rate compared to other algae. Lehman et al. (2017) reported that relatively small *Microcystis* blooms occurred in the 2004 and 2005 wet years when San Joaquin River flow was 28.32-35.40 m<sup>3</sup>s<sup>-1</sup>. A San Joaquin River flow of 9.1 m<sup>3</sup>s<sup>-1</sup>, a factor of three lower compared to 2004 and 2005 flows, produced the large 2014 *Microcystis* bloom. This is an important finding to put the flow and associated residence time effects of the CWF into context.

The Lehman et al (2017) study shows that very large reductions in flow (i.e., a factor of three lower) and associated very large increases in residence times can contribute to increased magnitude and duration of *Microcystis* blooms because the cells and colonies are not being flushed from the area as rapidly as would occur with lower residence times, and thus they accumulate in an area over time. As shown in Section 4.2 of this report, the effects of the CWF on channel velocities in the Delta is small compared to the large three-fold reduction in flow and

commensurate effects to velocity and residence time observed between 2014 and other years, where large effects on *Microcystis* were observed.

Other factors such as daily in-channel absolute velocities, turbulence, and mixing; competition with other algal species under the channel velocity conditions; and grazing losses to zooplankton, fish, and clams exert influences on blooms that will affect the amount of biomass that can accumulate over time for any given residence time, or increase in residence time for a site. Hence, greater residence time provides the opportunity for cyanobacteria to accumulate in areas of the Delta, without getting flushed from the area, but because of the other factors identified above that also affect the ability of cyanobacteria to accumulate in areas, a given magnitude increase in residence time will not always equate to a given magnitude increase in bloom size, or an increase in bloom size at all. The relationship between residence time (or increases in residence time at a location) and the size of *Microcystis* blooms (should a bloom occur at the site) would be expected to vary substantially by location within the Delta and by year due to how the factors listed above and other environmental factors vary temporally and spatially. Additional *Microcystis* research would be needed before definitive determinations regarding how changes in estimated residence time caused by the CWF would affect the magnitude of *Microcystis* blooms in the Delta can be made.

#### 4.4 TEMPERATURE EFFECTS OF THE CWF

Mr. Ringelberg claims the CWF would increase water temperatures due to loss of dilution. In his oral testimony Mr. Ringelberg states [Transcript vol. 29, pg. 53, Ln. 1–4], “...you take significant fractions of the coldest, highest quality of water out of the system, Sacramento River water, you're reducing the dilution effect and ultimately the assimilation capacity of this particular watershed.” [See also others who raise generalized temperature concerns, Mr. Strohshane RTD-10-rev2 p.38, ln.4–11; Ms. McCleary SCDA-62-errata p.3, ln.5–22.]

Mr. Ringelberg specifically claims water temperature in the Delta will increase. He states: “*The project will cause changes to water operations and creation of project-required tidal and floodplain restoration areas that change water residence times within Delta channels, and increases in Delta water temperatures.*” [Exhibit SJC-004, pg. 10, Ln. 21-23]. The only evidence he uses to support this claim regarding increased water temperatures is the testimony provided by Ms. Starr that addresses water temperature upstream of the Delta. In his oral testimony, he specifically relies on Ms. Starr as the source of his conclusion regarding temperature effects, stating: “*The quite extensive illustrations of the effects of operational changes and priorities to Folsom Dam and the consequential effects of temperature and clarity on what they believed to be significant impacts on their beneficial uses of water. We could go line by line through that, if you'd like.*”

*MS. ANSLEY: And would this be -- Just for my knowledge, would this be the testimony of Pravani Vandeyar and Bonny Starr?*

*WITNESS RINGELBERG: That's correct.*” [Transcript vol. 29, pg. 104–105, Ln. 20–25, 1–5].

Ms. Starr's testimony [Exhibit CITYSAC-8] was incorrect and is rebutted in Exhibit DWR-651. Mr. Ringelberg provides no assessment of any type to support his claim that the CWF would increase water temperatures in the Delta. As stated in the USFWS (2008b:194) OCAP BiOP, and as cited in the Final EIR/EIS, Chapter 8, p. 8-172.

The [state and federal] water projects have little if any ability to affect water temperatures In the Estuary (Kimmerer 2004). Estuarine and Delta water temperatures are driven by air temperature. Water temperatures at Freeport can be cooled up to about 3°C by high Sacramento River flows, but only by very high river flows that cannot be sustained by the projects. Note also that the cooling effect of the Sacramento River is not visible in data from the west Delta at Antioch (Kimmerer 2004) so the area of influence is limited.

While air temperature is the primary factor that drives Delta water temperatures, not Central Valley Project/State Water Project operations, I nevertheless provide the following assessment of how the CWF could potentially affect Delta water temperatures, based on modeling in the comparative mode to rebut Mr. Ringelberg's unsubstantiated claims about the effects of the CWF on Delta water temperatures.

***The small differences in water temperature between the CWF and NAA scenarios modeled for various locations across the Delta would not substantially increase the frequency or magnitude of cyanobacteria blooms within the Delta.***

This analysis compares modeled temperatures for the CWF to that modeled for the NAA as presented in the CWF Biological Assessment. The tables and figures supporting the analysis are provided in **Appendix A**. The nine locations selected for this analysis were based primarily on the availability of modeled temperature data, and thus they are not one-and-the-same with the nine locations assessed for velocity.

The CWF Biological Assessment provides temperature data for four locations in the Delta, which are: 1) lower Sacramento River at Rio Vista, 2) San Joaquin River at Prisoners Point, 3) San Joaquin River near Stockton Deep Water Ship Channel, and 4) San Joaquin River at Brant Bridge. The months of the year for which water temperatures at the four locations listed above exceed the 19°C (66.2°F) threshold below which *Microcystis* blooms have not been observed in the Delta are May through October. Consequently, this assessment will be limited to the months May through October, because cyanobacteria blooms are not expected to occur in the Delta during other months of the year, in most years, including most dry and critical years.

#### *Lower Sacramento River at Rio Vista*

Modeling shows that for the full simulation period (1922–2003), the period mean temperatures in the lower Sacramento River at Rio Vista for the CWF would be up to 0.1°C (0.18°F) higher than that modeled for the NAA for each month of the May through October period of the year. Likewise, the mean temperature for each month, by water year type, would not be more than 0.1°C (0.18°F) higher for the CWF, relative to the NAA. The frequency with which any given temperature above 19°C (66.2°F) would occur for the CWF would be very similar to that for the NAA (i.e., within about 5% or less) (Appendix A). The minor differences in river temperatures



at Rio Vista for the CWF, relative to the NAA, would not affect the frequency or magnitude of cyanobacteria blooms in this reach of the lower Sacramento River, relative to that which could occur for the NAA. It should also be noted that historical *Microcystis* abundance has substantially decreased moving north from Antioch. Hence, not only have *Microcystis* blooms not been a problem in the mainstem lower Sacramento River near Rio Vista historically, they are not expected to be a problem at this location for the CWF.

#### *San Joaquin River at Prisoners Point*

Modeling shows that for the full simulation period (1922-2003), the period mean temperatures in the San Joaquin River at Prisoners Point for the CWF would be up to 0.1°C (0.18°F) higher than that modeled for the NAA for each month of the May through October period of the year. Likewise, the mean temperature for each month, by water year type, would not be more than 0.1°C (0.18°F) higher for the CWF, relative to the NAA. The frequency with which any given temperature above 19°C (66.2°F) would be exceeded for the CWF would be very similar to that for the NAA (i.e., within about 5% or less). In September, the modeled maximum mean monthly temperature for the CWF would be about 0.3°C (0.6°F) higher than that modeled for the NAA (Appendix A). The minor differences in river temperature at Prisoners Point for the CWF, relative to the NAA, would not adversely affect the frequency or magnitude of cyanobacteria blooms in this reach of the San Joaquin River, relative to that which could occur for the NAA.

#### *San Joaquin River near Stockton Deep Water Ship Channel*

Modeling shows that for the full simulation period (1922–2003), the period mean temperatures in the San Joaquin River near the Stockton Deep Water Ship Channel for the CWF would be -0.1°C to 0.2°C (-0.18°F to 0.36°F) different than that modeled for the NAA, or for each month of the May through October period of the year. Likewise, the mean temperature for each month, by water year type, would not be more than 0.3°C (0.5°F) higher for the CWF, relative to the NAA, and would occasionally be up to 0.2°C (0.36°F) colder than the NAA. The frequency with which any given temperature above 19°C (66.2°F) would be exceeded for the CWF would be similar to that for the NAA (i.e., within about 7% or less) (Appendix A). In October, the maximum mean monthly temperature never exceeds the 19°C (66.2°F) for any of the scenarios, with 19°C (66.2°F) being the threshold below which problem-level *Microcystis* blooms have not been observed in the Delta. The minor differences in river temperature near the Stockton Deep Water Ship Channel for the CWF, relative to the NAA, would not affect the frequency or magnitude of cyanobacteria blooms in this reach of the San Joaquin River, relative to that which could occur for the NAA.

#### *San Joaquin River at Brandt Bridge*

Modeling shows that for the full simulation period (1922–2003), the period mean temperatures in the San Joaquin River at Brandt Bridge for the CWF would be within 0.1°C (0.18°F) of that modeled for the NAA, for each month of the May through October period of the year. Likewise, the mean temperature for each month, by water year type, would not be more than 0.1°C (0.18°F) higher for the CWF, relative to the NAA. The frequency with which any given temperature above 19°C (66.2°F) would be exceeded for the CWF would be nearly identical to

that for the NAA (Appendix A). The minor differences in river temperature at Brandt Bridge for the CWF, relative to the NAA, would not affect the frequency or magnitude of cyanobacteria blooms in this reach of the San Joaquin River, relative to that which could occur for the NAA.

In addition to the main-stem lower Sacramento and San Joaquin River locations presented above, DSM2-QUAL temperature modeling was conducted for five interior Delta locations, which are: Middle River at Middle River, Middle River at Bacon Island, Victoria Canal near Bryon, Old River at Holland Cut, and Old River at Clifton Court Ferry. Temperature probability exceedance plots for each location for the CWF (4A-H3+) and the NAA are presented in **Appendix A**, p. 9-11. This temperature modeling was not presented in either the Final EIR/EIS or the CWF Biological Assessment. These temperature exceedance plots show little to no difference in the frequency with which any given temperature would be exceeded for the CWF, relative to the NAA, for each of the five locations. This modeling provides additional evidence that the CWF would have minimal effects on Delta water temperatures.

Attachment 4 in Appendix 5B of the CWF Biological Assessment provides a detailed description of the assumptions and limitations for the DSM2 temperature modeling. The evaluation of DSM2 temperature modeling output described herein, conducted through a comparison of probability of exceedance with the CWF versus the NAA, is consistent with the temperature analysis approach in the Biological Assessment. This analysis did not rely upon the absolute results of the DSM2 temperature modeling, but rather used the modeling output in a comparative mode to determine the relative degree to which the CWF may affect Delta temperatures, relative to NAA, consistent with the appropriate use of this modeling.

Temperature modeling shows only very minor temperature changes (both increases and decreases) that could occur in the lower Sacramento River, San Joaquin River, and interior Delta locations due to the CWF, relative to temperatures that would occur for the NAA. A key reason the temperature changes are very small at these locations within the Delta is because by the time water released from upstream reservoirs reaches the Delta, it is typically at or close to equilibrium with ambient air temperatures. As such, flow differences between the CWF and the NAA that can have greater temperature effects in the rivers closer to the reservoir release locations generally result in minor temperature difference within the Delta. The minor differences in temperature in the lower Sacramento River at Rio Vista, San Joaquin River at Prisoners Point, San Joaquin River near Stockton Deep Water Ship Channel, San Joaquin River at Brant Bridge, Middle River at Middle River, Middle River at Bacon Island, Victoria Canal near Bryon, Old River at Holland Cut, and Old River at Clifton Court Ferry between the CWF and NAA scenarios would not be expected to substantially affect the frequency or magnitude of cyanobacteria blooms in these water bodies within the Delta, relative to that which would occur for the NAA.

#### 4.5 TURBIDITY EFFECTS OF THE CWF

Mr. Ringelberg claims the CWF will reduce turbidity, which will allow more light to enter the water column and cause greater problems with HABs. Mr. Ringelberg states, *“The significant reduction of sediment, thus influencing turbidity, results in greater sunlight penetration of the*

*water column. This light is likely to support phytoplankton, which get their energy from sunlight, and is understood to be one of the key controlling factors for HAB formation in the Delta.*” [Exhibit SJC-004, pg. 13, Ln. 4–7]. No evidence is provided to support this statement. Instead, the only evidence Mr. Ringelberg provides to support his claim that reduced turbidity will affect phytoplankton growth is a figure showing how the marine diatom, *Chaetoceros*, is affected by varying light levels [Exhibit SJC-004, SJC-066, pg. 19].

As stated in the Final EIR/EIS, Chapter 8, p. 8-971-972, the operation of the water conveyance facilities for the CWF is expected to have a minimal effect on total suspended solids (TSS) and turbidity levels in the Delta, relative to the NAA. This is because the factors that would affect TSS and turbidity within the Delta would remain the same. Turbidity and TSS levels in Delta waters are affected by TSS concentrations and turbidity levels of inflows (and associated sediment load), as well as fluctuation in flows within the channels due to the tides, with sediments depositing as flow velocities and turbulence are low at periods of slack tide, and sediments becoming suspended when flow velocities and turbulence increase when tides are near the maximum. Turbidity and TSS variations can also be attributed to phytoplankton, zooplankton and other biological material in the water. These factors would be similar under the CWF and the NAA.

The conclusion in the Final EIR/EIS is further confirmed by the analysis contained herein. The discussion provided in Section 4.2, above, indicated from DSM2 modeling output that daily maximum and 15-minute absolute channel velocities throughout the Delta for the CWF would not differ sufficiently from that which would occur for the NAA to result in hydrodynamics conditions substantially more favorable to cyanobacteria. It is the daily velocities in Delta channels, regardless of direction of flow, that generate much of the turbidity at any given site. Because channel velocities between the CWF and NAA scenarios differ little at the Delta locations assessed, in-channel, velocity driven turbidity also would be expected to differ little between these scenarios.

Further, cyanobacteria in the Delta are not light limited during the period of the year (May–October) when temperatures are warm enough to support cyanobacteria growth. For *Microcystis* in the Delta, the surface irradiance threshold is reached three months earlier than the water temperature threshold. Thus, temperature, not light, is the factor that limits cyanobacteria growth in the Delta (Lehman et al. 2013). In drought year of 2014, when *Microcystis* blooms were large in magnitude and duration, light levels in the euphotic zone were no greater than they were in previous years during the peak of the bloom (Lehman et al. 2017). In fact, Mr. Ringelberg contradicts his written testimony cited above in his oral testimony by stating that cyanobacteria in the Delta are not light limited. In his oral testimony, he stated: “*And since we have essentially full sunlight most of the year, during -- certainly during the growing period for algae, they are not light limited.*” [Transcript vol. 29, pg. 47, Ln. 1–3]. Because cyanobacteria are not light limited from June through November (Lehman et al. 2013) when other conditions are suitable for blooms, any minor change in turbidity that may occur from the CWF would not substantially affect the frequency or magnitude of cyanoHABs in the Delta.

#### 4.6 NUTRIENT EFFECTS OF THE CWF

Mr. Ringelberg, Mr. Burke, and Mr. Lee claim the CWF would increase nutrients in that Delta thereby causing cyanoHABs to become worse. [See also claims generally stated by Mr. Stroshane RTD-10-Rev2, p. 46:12-26, Mr. Broadksy SCDA-60 errata, p. 12:1- 18]

Mr. Ringelberg states: “*Reducing the flow of Sacramento River water through the Delta and concentrating the drainage of the San Joaquin River affects the dilution and the mixing of nutrients.*” [Exhibit SCDA\_33, pg. 2, Ln. 9–14].

Mr. Burke states: “*If diversions are shifted to the proposed NDD, this dilution effect will be reduced or eliminated. This will result in a higher nutrient loads for waters in and around Discovery Bay. All things being equal, higher nutrient loads can lead to algal blooms which reduce dissolved oxygen and lead to degradation of water quality.*” [Exhibit SCDA-35, pg. 2, Ln. 22–25].

Mr. Lee states: “*The proposed WaterFix project’s diversion of Sacramento River water will reduce the amount of Sacramento River water that enters the Central Delta and thereby impact the phosphorus input to the Central Delta and the phytoplankton population in that area of the Delta. The reduction in dilution of phosphorus concentration in the Central Delta leads to impaired water quality and adverse impacts/injuries to the public/users of Central Delta waters.*” [Exhibit CSPA-6-Revised, pg. 17].

Mr. Ringelberg, Mr. Burke and Mr. Lee (as well as Mr. Shroshane and Mr. Broadsky) did not provide any evidence to support their claims cited above. Consequently, their claims suggesting that the CWF would increase nutrients in areas of the Delta that would then cause greater cyanoHABs are speculative and unsupported.

***The small increases in nutrients in portions of the Delta due to the CWF would not be expected to increase the frequency, magnitude, or duration of cyanoHAB in the Delta, relative to that which would occur for the NAA.***

Based on the modified system operations, the CWF scenarios would increase the amount of San Joaquin River water and decrease the amount of Sacramento River water at various central Delta locations. Because the San Joaquin River generally has higher concentrations of total nitrogen compounds (N) and total phosphorus compounds (P) compared to the lower Sacramento River, it is expected that total N and P levels in the central Delta would increase somewhat for the CWF scenarios.

There are three forms of nitrogen that are commonly measured in water bodies, which are: ammonia, nitrates and nitrites. Total nitrogen (total N) is the sum of total kjeldahl nitrogen (ammonia, organic and reduced nitrogen) and nitrate and nitrite. Total N is available in non-limiting amounts for *Microcystis* in the Delta (Lehman et al. 2008, 2017; Berg and Sutula 2015). Lehman et al. (2017) found that although Delta nitrate concentrations were always above analytical detection limits and dominated the dissolved inorganic nitrogen pool, ammonium

(NH<sub>4</sub><sup>+</sup>) was the primary source of nitrogen for the *Microcystis* bloom in 2014. *Microcystis* favored ammonium, even when ammonium was low to below detection limits and nitrate was available in excess (Lehman et al. 2017).

Orthophosphate or soluble reactive phosphorus (SRP) – the form directly taken up by plant cells – also is available in non-limiting amounts in the Delta (Lehman et al. 2008, 2017; Berg and Sutula 2015). Moreover, Lehman et al. (2017) reported that there was no clear link between the large increase in orthophosphate (referred to by Lehman as SRP) in the 2014 drought condition and elevated *Microcystis* biomass or chlorophyll *a* concentration in the Delta in 2014. Bioassays have shown that the addition of only orthophosphate does not enhance growth in *Microcystis* blooms in the Klamath River, Oregon; Lake Taihu, China; or Lake Erie, Michigan (Moisander et al. 2009, Xu et al. 2010, Chaffin et al. 2013 as cited in Lehman et al. 2017).

The maintenance of *Microcystis* blooms requires the availability of the macronutrients nitrogen and phosphorus but there was no suggestion from study data that these nutrients or their ratio controlled the seasonal or inter-annual variation in the bloom (Lehman et al. 2013). Based on their comprehensive review of the available literature to provide insight into cyanobacteria blooms in the Delta, Berg and Sutula (2015) found that nutrient concentrations and N:P ratios do not change sufficiently among years to explain inter-annual variation in *Microcystis* biomass or occurrence. They further stated: “*Therefore, the initiation of Microcystis blooms and other cyanoHABs are probably not associated with changes in nutrient concentrations or their ratios in the Delta.*” Nutrient ratios also do not vary between pre- and post-bloom in the Delta, indicating that nutrients are in excess of phytoplankton demand for the entire summer season (Berg and Sutula 2015). Total N and orthophosphate (SRP) concentrations were well in excess during the *Microcystis* bloom in 2014 and the N:P ratio was not correlated with *Microcystis* biovolume (Lehman et al. 2017).

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## Appendix A

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Delta Monthly Mean Temperatures at Nine Locations for the CWF and NAA

Sacramento River at Rio Vista, Monthly Temperature

Statistic	Monthly Temperature (Deg-C)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
<b>Probability of Exceedance<sup>a</sup></b>																								
10%	18.2	18.2	0.0	0%	14.9	15.0	0.1	1%	10.7	10.7	0	0%	9.7	9.7	0.0	0%	11.1	11.1	0.0	0%	14.2	14.2	0.0	0%
20%	17.9	18.1	0.1	1%	14.5	14.7	0.2	2%	10.5	10.5	0	0%	9.5	9.5	0.0	0%	11.0	11.0	0.0	0%	13.7	13.8	0.0	0%
30%	17.8	17.8	0.1	0%	14.4	14.4	0.0	0%	10.4	10.4	0	0%	9.2	9.3	0.1	1%	10.9	10.9	0.0	0%	13.4	13.5	0.1	1%
40%	17.5	17.5	0.0	0%	14.2	14.3	0.0	0%	10.2	10.2	0	0%	9.1	9.1	0.0	0%	10.7	10.8	0.0	0%	13.3	13.3	0.0	0%
50%	17.3	17.3	0.0	0%	14.0	14.1	0.1	0%	10.1	10.1	0	0%	9.0	9.0	0.0	0%	10.6	10.6	0.0	0%	13.0	13.0	0.1	0%
60%	17.1	17.2	0.0	0%	13.8	13.8	0.0	0%	10.0	10.0	0	0%	8.9	8.9	0.0	0%	10.4	10.4	0.0	0%	12.7	12.8	0.0	0%
70%	16.9	16.9	0.0	0%	13.6	13.7	0.1	0%	9.8	9.8	0	0%	8.8	8.8	0.0	0%	10.3	10.3	0.0	0%	12.6	12.6	0.0	0%
80%	16.6	16.7	0.0	0%	13.3	13.3	0.0	0%	9.7	9.7	0	0%	8.4	8.4	0.0	0%	10.1	10.2	0.0	0%	12.4	12.5	0.1	1%
90%	16.4	16.4	0.0	0%	12.9	12.9	0.0	0%	9.4	9.5	0	0%	8.1	8.0	0.0	0%	10.0	10.0	0.0	0%	12.0	12.0	0.0	0%
<b>Long Term Full Simulation Period<sup>b</sup></b>	17.3	17.3	0.0	0%	13.9	14.0	0.1	0%	10.1	10.1	0	0%	9.0	9.0	0.0	0%	10.6	10.6	0.0	0%	13.0	13.1	0.1	0%
<b>Water Year Types<sup>c</sup></b>																								
Wet (32%)	17.3	17.4	0.1	0%	13.9	14.0	0.1	1%	10.1	10.1	0	0%	9.1	9.1	0.0	0%	10.5	10.5	0.0	0%	12.7	12.7	0.1	0%
Above Normal (16%)	15.7	15.8	0.0	0%	12.5	12.6	0.1	1%	9.2	9.2	0	0%	9.3	9.3	0.0	0%	10.6	10.7	0.0	0%	13.0	13.0	0.0	0%
Below Normal (13%)	17.4	17.4	0.0	0%	14.1	14.2	0.1	1%	10.0	10.0	0	0%	8.8	8.8	0.0	0%	10.4	10.4	0.0	0%	13.0	13.1	0.1	0%
Dry (24%)	17.3	17.3	0.0	0%	14.0	14.1	0.1	0%	10.2	10.3	0	0%	8.7	8.7	0.0	0%	10.6	10.6	0.0	0%	13.0	13.1	0.1	0%
Critical (15%)	17.6	17.6	0.0	0%	14.1	14.1	0.0	0%	10.1	10.2	0	0%	8.8	8.8	0.0	0%	10.7	10.8	0.0	0%	13.8	13.8	0.0	0%

Statistic	Monthly Temperature (Deg-C)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
<b>Probability of Exceedance<sup>a</sup></b>																								
10%	15.9	15.9	0.0	0%	18.2	18.2	0.0	0%	20.7	20.8	0	0%	22.2	22.3	0.2	1%	22.1	22.3	0.2	1%	20.7	20.8	0.1	0%
20%	15.5	15.5	0.0	0%	18.0	18.0	0.0	0%	20.4	20.4	0	0%	21.9	21.9	0.1	0%	21.8	21.8	0.1	0%	20.5	20.6	0.0	0%
30%	15.2	15.2	0.0	0%	17.8	17.8	0.0	0%	20.2	20.2	0	0%	21.7	21.8	0.1	0%	21.7	21.7	0.0	0%	20.4	20.5	0.1	0%
40%	14.9	15.0	0.0	0%	17.6	17.6	0.0	0%	19.9	19.9	0	0%	21.5	21.7	0.1	1%	21.5	21.5	0.0	0%	20.2	20.3	0.1	0%
50%	14.7	14.7	0.0	0%	17.5	17.5	0.0	0%	19.7	19.6	0	0%	21.3	21.4	0.1	0%	21.4	21.4	0.0	0%	20.1	20.1	0.0	0%
60%	14.5	14.5	0.0	0%	17.5	17.4	0.0	0%	19.5	19.5	0	0%	21.1	21.1	0.0	0%	21.2	21.2	0.0	0%	20.0	19.9	0.0	0%
70%	14.4	14.4	0.0	0%	17.2	17.2	0.0	0%	19.2	19.2	0	0%	20.9	20.9	0.0	0%	21.2	21.2	0.0	0%	19.8	19.8	0.0	0%
80%	14.2	14.2	0.0	0%	17.1	17.1	0.0	0%	19.1	19.0	0	0%	20.8	20.8	0.0	0%	21.0	20.9	-0.1	0%	19.6	19.6	0.0	0%
90%	14.1	14.1	0.0	0%	16.5	16.5	0.0	0%	18.8	18.7	0	-1%	20.7	20.7	0.0	0%	20.9	20.8	-0.1	0%	19.3	19.2	-0.1	0%
<b>Long Term Full Simulation Period<sup>b</sup></b>	14.8	14.8	0.0	0%	17.5	17.5	0.0	0%	19.7	19.7	0	0%	21.4	21.4	0.1	0%	21.4	21.4	0.0	0%	20.1	20.1	0.0	0%
<b>Water Year Types<sup>c</sup></b>																								
Wet (32%)	14.5	14.5	0.0	0%	17.5	17.5	0.0	0%	19.4	19.4	0	0%	21.3	21.4	0.1	0%	21.5	21.5	0.0	0%	20.2	20.3	0.0	0%
Above Normal (16%)	14.8	14.8	0.0	0%	17.6	17.6	0.0	0%	20.0	20.0	0	0%	21.4	21.4	0.0	0%	21.2	21.2	0.0	0%	20.0	20.0	0.0	0%
Below Normal (13%)	15.2	15.2	0.0	0%	17.4	17.4	0.0	0%	19.7	19.7	0	0%	21.4	21.5	0.1	0%	21.3	21.3	0.0	0%	19.9	19.9	0.1	0%
Dry (24%)	15.0	15.0	0.0	0%	17.6	17.6	0.0	0%	20.1	20.1	0	0%	21.5	21.5	0.1	0%	21.4	21.4	0.0	0%	20.1	20.1	0.0	0%
Critical (15%)	15.0	15.0	0.0	0%	17.5	17.5	0.0	0%	19.3	19.3	0	0%	21.5	21.5	0.0	0%	21.4	21.4	0.0	0%	19.9	19.9	0.0	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.

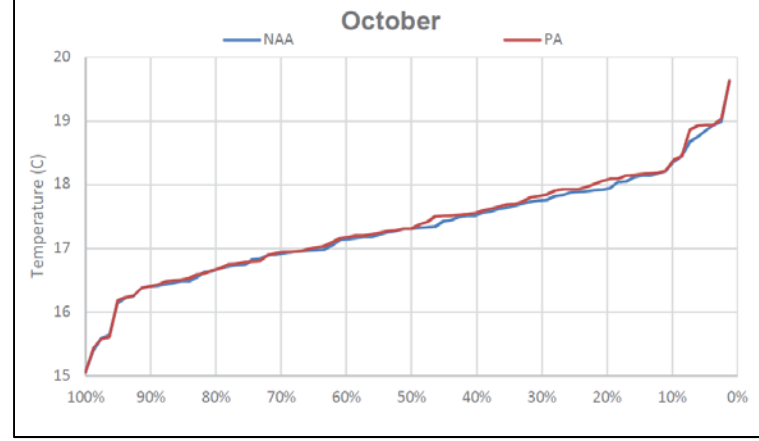
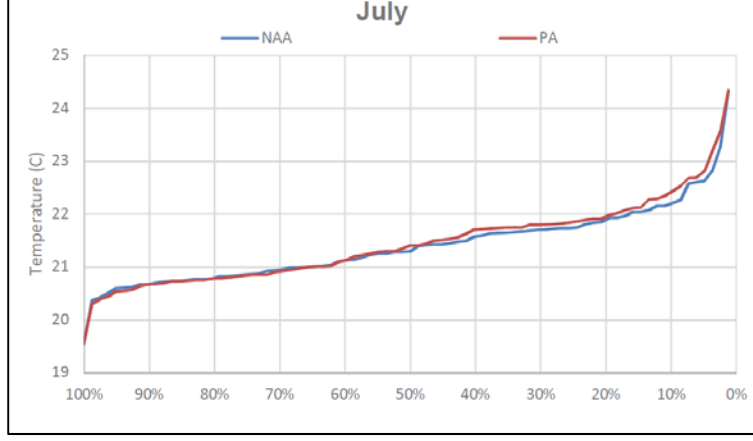
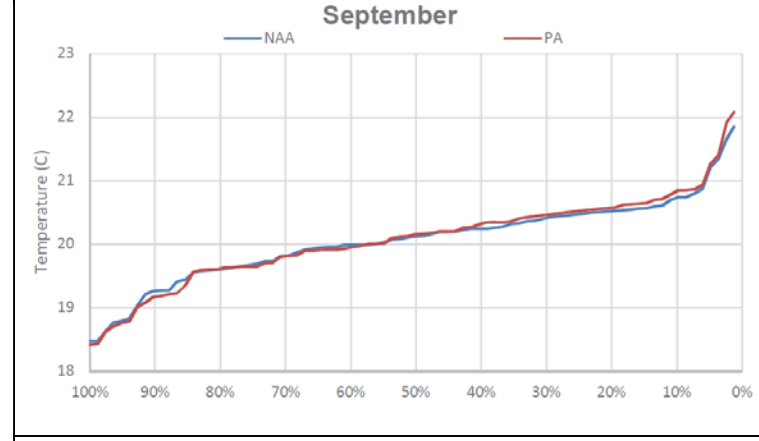
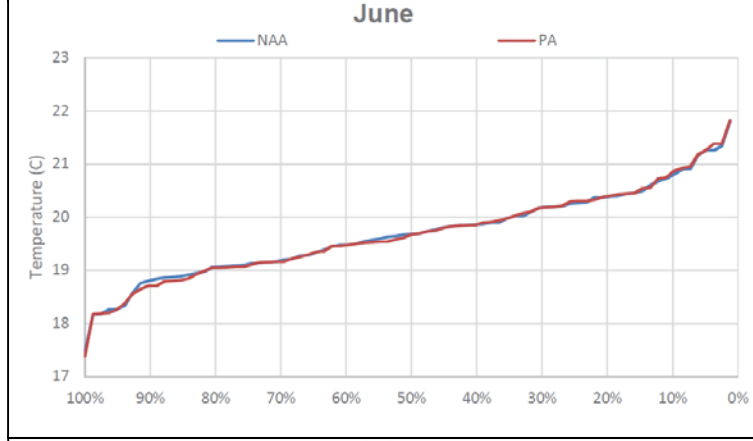
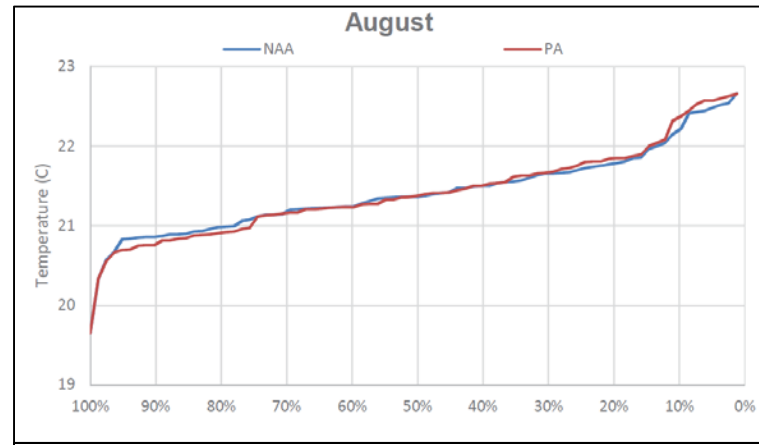
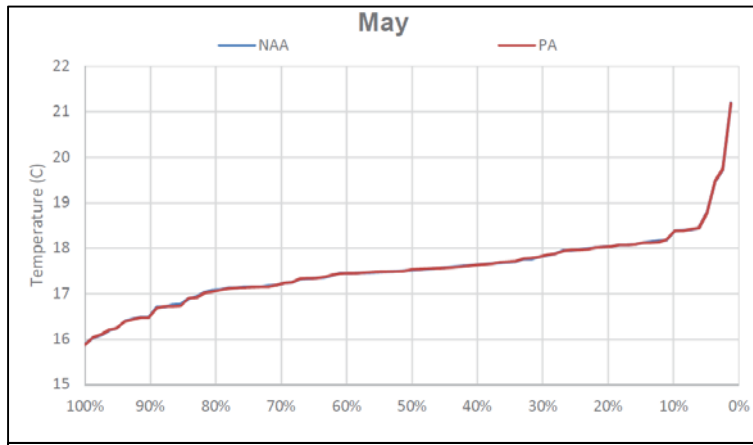
b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

Source: Biological Assessment, Appendix 5.B, DSM2 Modeling and Results

# Sacramento River at Rio Vista, Monthly Temperature



Source: Biological Assessment, Appendix 5B, Figure 5.B.5.40-1

San Joaquin River at Prisoners Point, Monthly Temperature

Statistic	Monthly Temperature (Deg-C)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance <sup>a</sup>																								
10%	18.5	18.5	0.0	0%	15.5	15.5	0.0	0%	11.6	11.6	0	0%	10.4	10.6	0.1	1%	11.9	12.1	0.1	1%	14.6	15.0	0.4	3%
20%	18.3	18.3	0.0	0%	15.2	15.2	0.0	0%	11.3	11.3	0	1%	10.0	10.0	0.1	1%	11.6	11.9	0.2	2%	14.3	14.6	0.3	2%
30%	18.0	18.1	0.0	0%	14.9	14.9	0.1	0%	11.1	11.1	0	1%	9.7	9.8	0.1	1%	11.4	11.6	0.2	2%	14.0	14.3	0.3	2%
40%	17.9	17.8	-0.1	-1%	14.7	14.7	0.1	0%	11.0	11.0	0	0%	9.4	9.5	0.1	1%	11.2	11.3	0.1	1%	13.8	14.0	0.2	1%
50%	17.6	17.6	0.0	0%	14.5	14.6	0.1	0%	10.8	10.8	0	0%	9.3	9.3	0.0	0%	11.0	11.1	0.2	1%	13.6	13.7	0.2	1%
60%	17.4	17.4	-0.1	0%	14.4	14.2	-0.2	-1%	10.6	10.7	0	0%	9.0	9.1	0.1	1%	10.8	11.0	0.2	2%	13.3	13.7	0.3	2%
70%	17.3	17.2	-0.1	0%	14.1	14.0	0.0	0%	10.5	10.6	0	1%	8.8	8.9	0.1	1%	10.6	10.8	0.1	1%	13.1	13.4	0.3	2%
80%	17.0	16.9	-0.1	-1%	13.9	13.8	-0.1	0%	10.3	10.4	0	1%	8.5	8.5	0.0	0%	10.2	10.3	0.1	1%	13.0	13.2	0.2	2%
90%	16.8	16.7	-0.1	-1%	13.2	13.1	-0.1	0%	9.9	9.9	0	0%	8.0	8.0	0.0	0%	9.9	10.0	0.1	1%	12.7	12.9	0.2	2%
Long Term Full Simulation Period <sup>b</sup>	17.5	17.4	0.0	0%	14.3	14.3	0.0	0%	10.7	10.7	0	0%	9.3	9.3	0.1	1%	10.9	11.1	0.2	2%	13.6	13.9	0.3	2%
Water Year Types <sup>c</sup>																								
Wet (32%)	17.8	17.7	-0.1	0%	14.5	14.4	-0.1	-1%	10.8	10.8	0	0%	9.6	9.7	0.1	1%	11.4	11.6	0.3	2%	13.7	14.0	0.3	2%
Above Normal (16%)	16.1	16.0	-0.1	0%	13.0	12.9	-0.1	0%	9.7	9.8	0	1%	9.8	9.9	0.1	1%	11.1	11.3	0.2	2%	13.7	14.2	0.5	3%
Below Normal (13%)	17.6	17.6	0.0	0%	14.6	14.6	0.0	0%	10.7	10.8	0	0%	9.0	9.1	0.1	1%	10.5	10.6	0.1	1%	13.3	13.7	0.3	2%
Dry (24%)	17.6	17.6	0.0	0%	14.6	14.6	0.1	0%	11.1	11.1	0	0%	8.8	8.9	0.1	1%	10.7	10.8	0.1	1%	13.4	13.6	0.2	1%
Critical (15%)	17.9	17.8	0.0	0%	14.7	14.6	0.0	0%	10.9	10.9	0	0%	8.8	8.8	0.0	0%	10.6	10.7	0.0	0%	14.0	14.1	0.1	1%

Statistic	Monthly Temperature (Deg-C)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance <sup>a</sup>																								
10%	16.4	16.4	0.0	0%	18.3	18.3	0.0	0%	20.8	20.8	0	0%	22.4	22.5	0.1	1%	22.3	22.5	0.2	1%	20.9	21.0	0.1	0%
20%	15.9	16.0	0.1	1%	18.0	18.1	0.0	0%	20.3	20.3	0	0%	22.0	22.0	0.1	0%	21.9	22.0	0.1	0%	20.7	20.8	0.1	0%
30%	15.6	15.7	0.1	1%	17.9	17.9	0.0	0%	20.0	20.0	0	0%	21.8	21.9	0.1	0%	21.8	21.8	0.0	0%	20.6	20.6	0.0	0%
40%	15.3	15.3	0.1	0%	17.5	17.6	0.1	0%	19.7	19.8	0	1%	21.7	21.7	0.0	0%	21.6	21.6	0.0	0%	20.4	20.4	0.0	0%
50%	15.0	15.1	0.1	0%	17.3	17.4	0.0	0%	19.5	19.6	0	1%	21.4	21.4	0.0	0%	21.5	21.5	0.0	0%	20.3	20.2	0.0	0%
60%	14.8	14.9	0.2	1%	17.1	17.2	0.1	1%	19.4	19.4	0	0%	21.2	21.2	0.0	0%	21.4	21.3	0.0	0%	20.1	20.0	-0.1	0%
70%	14.6	14.8	0.1	1%	16.9	16.9	0.0	0%	19.1	19.1	0	0%	20.9	20.9	0.0	0%	21.2	21.2	0.0	0%	19.9	19.9	0.0	0%
80%	14.4	14.5	0.2	1%	16.7	16.7	0.0	0%	18.8	18.8	0	0%	20.8	20.7	0.0	0%	21.0	21.0	0.0	0%	19.8	19.6	-0.2	-1%
90%	13.7	13.9	0.2	1%	16.3	16.4	0.1	0%	18.6	18.6	0	0%	20.6	20.5	-0.1	0%	20.9	20.9	-0.1	0%	19.3	19.2	-0.1	0%
Long Term Full Simulation Period <sup>b</sup>	15.1	15.2	0.1	1%	17.4	17.4	0.1	0%	19.6	19.6	0	0%	21.4	21.5	0.0	0%	21.5	21.5	0.0	0%	20.2	20.2	0.0	0%
Water Year Types <sup>c</sup>																								
Wet (32%)	14.9	15.0	0.1	1%	17.4	17.4	0.0	0%	19.4	19.5	0	1%	21.4	21.4	0.0	0%	21.6	21.7	0.0	0%	20.4	20.4	0.0	0%
Above Normal (16%)	15.0	15.1	0.1	1%	17.4	17.4	0.1	0%	19.9	20.0	0	0%	21.4	21.4	0.0	0%	21.4	21.4	0.0	0%	20.1	20.0	0.0	0%
Below Normal (13%)	15.3	15.4	0.1	1%	17.3	17.4	0.0	0%	19.5	19.5	0	0%	21.5	21.5	0.0	0%	21.4	21.4	0.0	0%	20.1	20.1	0.0	0%
Dry (24%)	15.2	15.3	0.1	1%	17.4	17.5	0.0	0%	20.0	20.0	0	0%	21.5	21.6	0.0	0%	21.5	21.5	0.0	0%	20.2	20.2	0.0	0%
Critical (15%)	15.1	15.2	0.0	0%	17.3	17.3	0.0	0%	19.1	19.1	0	0%	21.4	21.4	0.0	0%	21.5	21.5	0.0	0%	20.1	20.1	0.0	0%

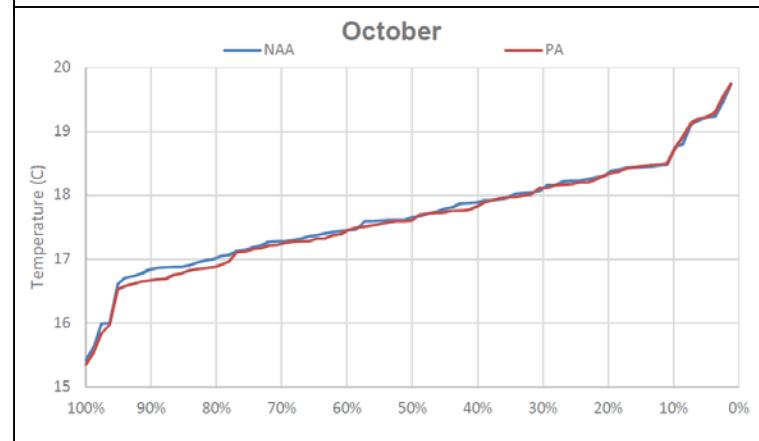
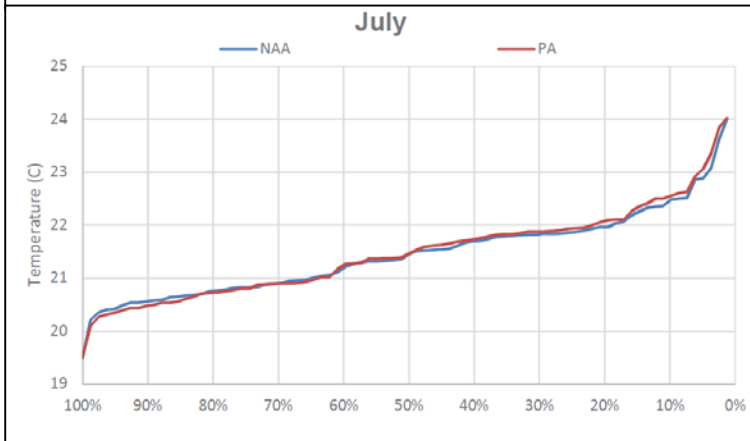
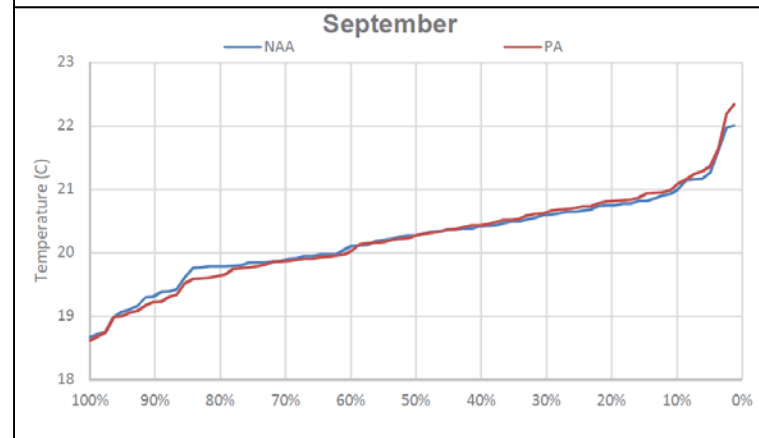
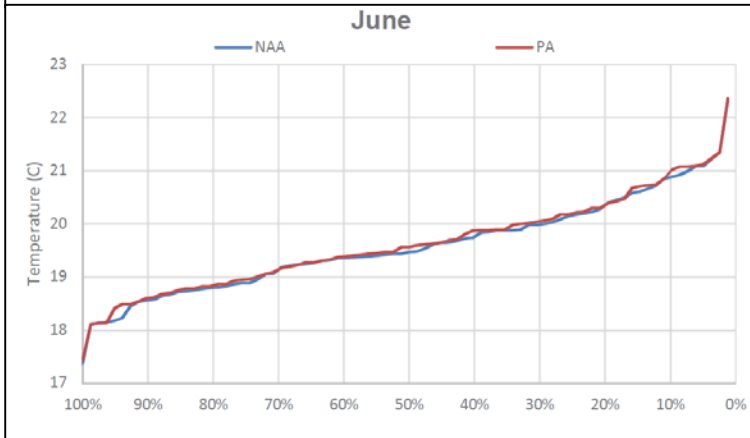
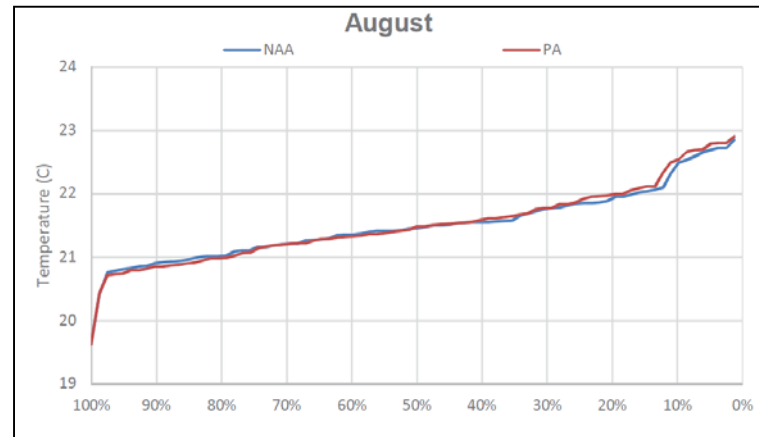
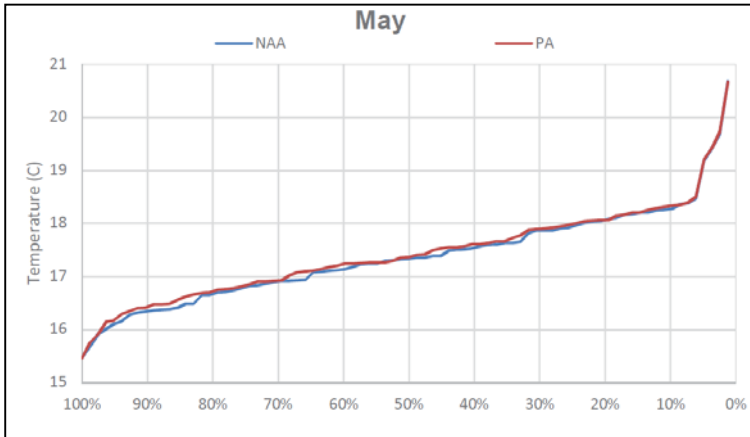
a Exceedance probability is defined as the probability a given value will be exceeded in any one year.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

# San Joaquin River at Prisoner's Point, Monthly Temperature



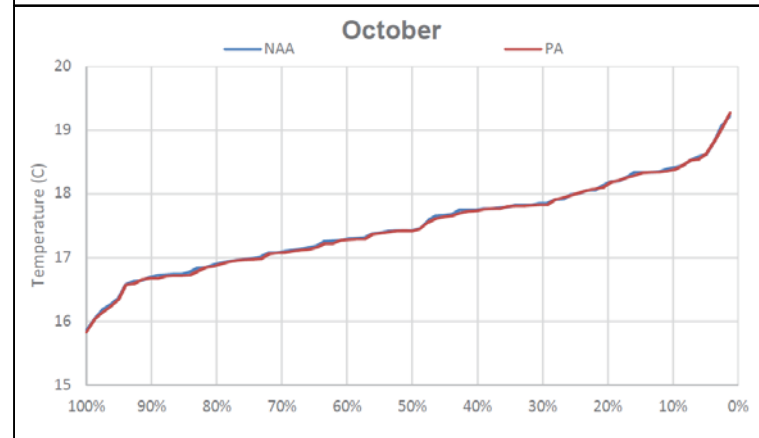
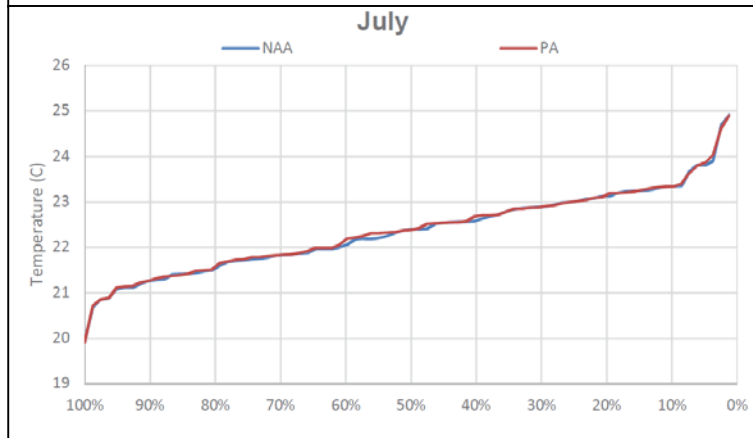
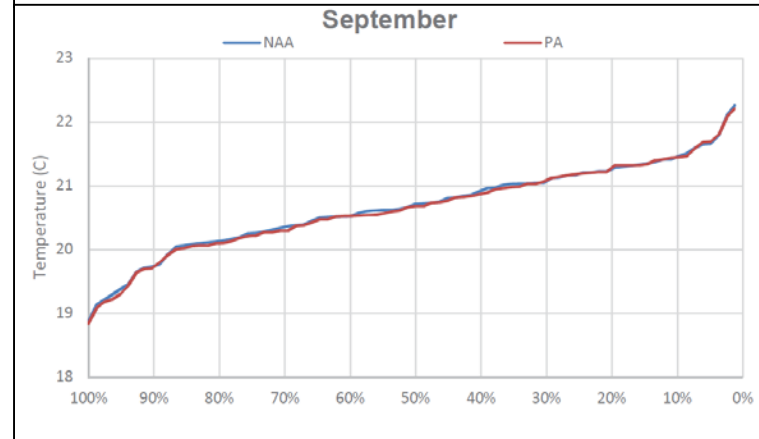
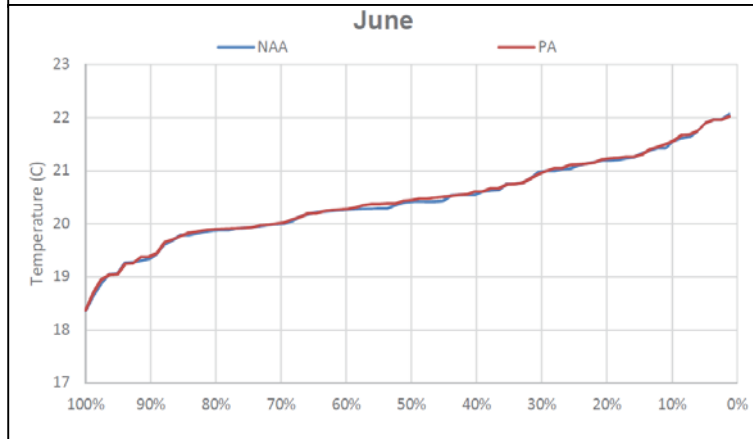
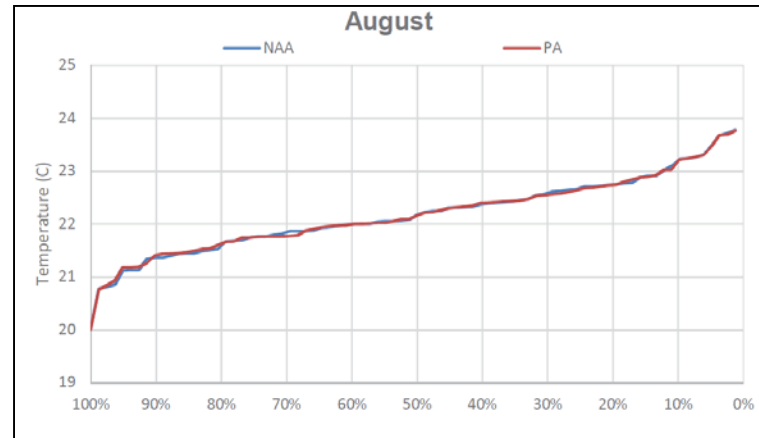
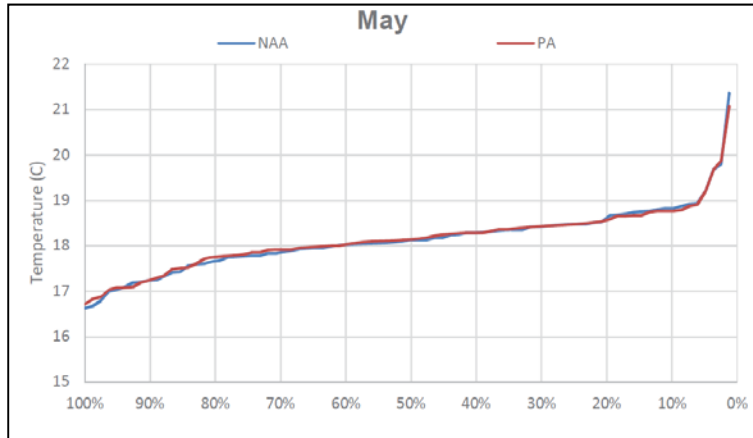
Source: Biological Assessment, Appendix 5B, Figure 5.B.5.41-1

San Joaquin River at Brandt Bridge, Monthly Temperature

Statistic	Monthly Temperature (Deg-C)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
<b>Probability of Exceedance<sup>a</sup></b>																								
10%	18.4	18.4	0.0	0%	14.7	14.6	0.0	0%	11.0	11.0	0	0%	10.7	10.7	0.0	0%	12.7	12.6	0.0	0%	15.6	15.4	-0.2	-1%
20%	18.1	18.1	0.0	0%	14.3	14.3	0.0	0%	10.7	10.7	0	0%	10.4	10.4	0.0	0%	12.5	12.4	0.0	0%	15.2	15.2	0.0	0%
30%	17.8	17.8	0.0	0%	14.1	14.1	0.0	0%	10.3	10.3	0	0%	10.3	10.3	0.0	0%	12.3	12.3	0.0	0%	14.9	14.8	-0.1	-1%
40%	17.8	17.7	0.0	0%	14.0	14.0	0.0	0%	10.2	10.2	0	0%	10.1	10.1	0.0	0%	12.1	12.1	0.0	0%	14.5	14.5	0.0	0%
50%	17.4	17.4	0.0	0%	13.8	13.7	0.0	0%	10.0	10.0	0	0%	10.0	10.0	0.1	1%	12.0	12.0	0.0	0%	14.3	14.3	0.0	0%
60%	17.3	17.2	0.0	0%	13.6	13.6	0.0	0%	9.9	9.9	0	0%	9.8	9.8	0.1	1%	11.8	11.9	0.0	0%	14.1	14.1	0.0	0%
70%	17.1	17.1	0.0	0%	13.4	13.4	0.0	0%	9.7	9.7	0	0%	9.5	9.6	0.1	1%	11.7	11.7	0.0	0%	14.0	14.0	0.0	0%
80%	16.9	16.9	0.0	0%	13.1	13.1	0.0	0%	9.6	9.6	0	0%	9.1	9.2	0.1	1%	11.6	11.6	0.0	0%	13.7	13.7	0.0	0%
90%	16.6	16.7	0.0	0%	12.6	12.5	0.0	0%	9.2	9.2	0	0%	8.7	8.9	0.2	2%	11.4	11.4	0.0	0%	13.3	13.4	0.0	0%
<b>Long Term Full Simulation Period<sup>b</sup></b>	17.3	17.3	0.0	0%	13.6	13.5	0.0	0%	10.0	10.0	0	0%	9.8	9.9	0.1	1%	12.0	12.0	0.0	0%	14.4	14.4	0.0	0%
<b>Water Year Types<sup>c</sup></b>																								
Wet (32%)	17.6	17.6	0.0	0%	13.9	13.8	0.0	0%	10.2	10.2	0	0%	10.1	10.2	0.0	0%	12.0	12.0	0.0	0%	14.2	14.2	0.0	0%
Above Normal (16%)	15.9	15.9	0.0	0%	12.4	12.3	0.0	0%	9.2	9.2	0	0%	10.2	10.3	0.0	0%	12.1	12.1	0.0	0%	14.5	14.5	0.0	0%
Below Normal (13%)	17.5	17.5	0.0	0%	13.8	13.8	0.0	0%	9.9	9.9	0	0%	9.6	9.7	0.1	1%	11.8	11.8	0.0	0%	14.3	14.3	0.0	0%
Dry (24%)	17.4	17.4	0.0	0%	13.7	13.7	0.0	0%	10.3	10.3	0	0%	9.5	9.6	0.1	1%	12.0	12.0	0.0	0%	14.5	14.5	0.0	0%
Critical (15%)	17.6	17.6	0.0	0%	13.7	13.7	0.0	0%	10.0	10.0	0	0%	9.6	9.7	0.1	1%	12.0	12.0	0.0	0%	15.0	14.9	-0.1	-1%
Statistic	Monthly Temperature (Deg-C)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
<b>Probability of Exceedance<sup>a</sup></b>																								
10%	16.9	16.9	0.0	0%	18.8	18.8	-0.1	0%	21.4	21.5	0	0%	23.3	23.3	0.0	0%	23.1	23.0	-0.1	0%	21.4	21.4	0.0	0%
20%	16.5	16.5	0.0	0%	18.5	18.5	0.0	0%	21.2	21.2	0	0%	23.1	23.1	0.0	0%	22.7	22.7	0.0	0%	21.2	21.2	0.0	0%
30%	16.3	16.3	0.0	0%	18.4	18.4	0.0	0%	20.9	20.9	0	0%	22.9	22.9	0.0	0%	22.6	22.5	0.0	0%	21.0	21.1	0.0	0%
40%	16.1	16.1	0.0	0%	18.3	18.3	0.0	0%	20.5	20.6	0	0%	22.6	22.6	0.1	0%	22.4	22.4	0.0	0%	20.9	20.9	0.0	0%
50%	15.7	15.8	0.0	0%	18.1	18.1	0.0	0%	20.4	20.4	0	0%	22.4	22.4	0.0	0%	22.1	22.1	0.0	0%	20.7	20.7	0.0	0%
60%	15.6	15.6	0.0	0%	18.0	18.0	0.0	0%	20.3	20.3	0	0%	22.0	22.1	0.1	0%	22.0	22.0	0.0	0%	20.5	20.5	0.0	0%
70%	15.4	15.4	0.0	0%	17.8	17.9	0.1	0%	20.0	20.0	0	0%	21.8	21.8	0.0	0%	21.8	21.8	-0.1	0%	20.3	20.3	0.0	0%
80%	15.2	15.2	0.0	0%	17.7	17.8	0.1	1%	19.9	19.9	0	0%	21.5	21.5	0.0	0%	21.6	21.6	0.1	0%	20.1	20.1	0.0	0%
90%	14.9	14.9	0.0	0%	17.2	17.2	0.0	0%	19.3	19.4	0	0%	21.3	21.3	0.0	0%	21.4	21.4	0.0	0%	19.7	19.7	0.0	0%
<b>Long Term Full Simulation Period<sup>b</sup></b>	15.8	15.8	0.0	0%	18.1	18.1	0.0	0%	20.4	20.5	0	0%	22.4	22.4	0.0	0%	22.2	22.2	0.0	0%	20.7	20.6	0.0	0%
<b>Water Year Types<sup>c</sup></b>																								
Wet (32%)	15.6	15.6	0.0	0%	18.2	18.2	0.0	0%	20.5	20.5	0	0%	22.9	22.9	0.0	0%	22.7	22.7	0.0	0%	21.1	21.1	0.0	0%
Above Normal (16%)	15.8	15.8	0.0	0%	18.2	18.2	0.0	0%	20.8	20.8	0	0%	22.3	22.3	0.0	0%	22.0	22.0	0.0	0%	20.7	20.7	0.0	0%
Below Normal (13%)	16.2	16.3	0.1	0%	17.8	17.8	0.1	0%	20.4	20.5	0	0%	22.2	22.2	0.0	0%	21.9	21.9	0.0	0%	20.5	20.5	0.0	0%
Dry (24%)	15.9	15.9	0.0	0%	18.2	18.2	0.0	0%	20.6	20.7	0	0%	22.0	22.1	0.1	0%	22.0	22.0	0.0	0%	20.5	20.5	0.0	0%
Critical (15%)	15.9	15.9	0.0	0%	18.1	18.1	0.0	0%	19.6	19.6	0	0%	22.0	22.0	0.0	0%	21.8	21.8	0.0	0%	20.2	20.2	0.0	0%
<sup>a</sup> Exceedance probability is defined as the probability a given value will be exceeded in any one year. <sup>b</sup> Based on the 82-year simulation period. <sup>c</sup> As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II. <sup>d</sup> There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.																								



# San Joaquin River at Brandt Bridge, Monthly Temperature



Source: Biological Assessment, Appendix 5B, Figure 5.B.5.42-1



San Joaquin River near Stockton DWSC, Monthly Temperature

Statistic	Monthly Temperature (Deg-C)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
<b>Probability of Exceedance<sup>a</sup></b>																								
10%	18.0	18.0	0.0	0%	14.4	14.4	0.0	0%	10.9	10.9	0	-1%	10.3	10.5	0.2	2%	12.2	12.3	0.1	1%	15.1	15.2	0.2	1%
20%	17.7	17.7	0.0	0%	14.0	14.0	0.0	0%	10.4	10.4	0	0%	10.0	10.1	0.2	2%	11.9	12.1	0.2	2%	14.8	15.0	0.1	1%
30%	17.4	17.4	0.0	0%	13.8	13.8	0.0	0%	9.9	9.9	0	0%	9.7	10.0	0.3	3%	11.7	12.0	0.3	2%	14.4	14.5	0.1	1%
40%	17.2	17.2	-0.1	0%	13.6	13.6	0.0	0%	9.6	9.6	0	0%	9.4	9.7	0.3	3%	11.6	11.8	0.2	1%	14.1	14.3	0.2	1%
50%	16.9	17.0	0.0	0%	13.5	13.5	0.0	0%	9.5	9.5	0	0%	9.1	9.5	0.3	4%	11.4	11.7	0.2	2%	13.8	14.0	0.2	1%
60%	16.7	16.7	-0.1	0%	13.3	13.3	0.0	0%	9.4	9.4	0	0%	8.9	9.3	0.4	5%	11.4	11.5	0.2	2%	13.7	13.9	0.2	1%
70%	16.5	16.5	0.0	0%	13.1	13.1	0.0	0%	9.2	9.2	0	0%	8.5	9.1	0.6	7%	11.1	11.4	0.3	3%	13.6	13.7	0.1	1%
80%	16.2	16.3	0.1	1%	12.7	12.7	0.0	0%	9.0	9.0	0	0%	8.1	8.7	0.6	7%	10.9	11.3	0.3	3%	13.3	13.6	0.3	2%
90%	16.1	16.1	0.0	0%	12.3	12.3	0.0	0%	8.7	8.7	0	0%	7.6	8.2	0.6	8%	10.5	10.9	0.5	5%	12.9	13.2	0.3	2%
<b>Long Term Full Simulation Period<sup>b</sup></b>	16.8	16.8	0.0	0%	13.3	13.3	0.0	0%	9.5	9.5	0	0%	9.0	9.4	0.4	4%	11.4	11.6	0.3	2%	14.0	14.1	0.2	1%
<b>Water Year Types<sup>c</sup></b>																								
Wet (32%)	17.2	17.2	0.0	0%	13.6	13.6	0.0	0%	9.7	9.7	0	0%	9.7	9.9	0.2	2%	11.8	11.9	0.1	1%	14.0	14.1	0.1	0%
Above Normal (16%)	15.5	15.5	0.0	0%	12.1	12.1	0.0	0%	8.7	8.7	0	0%	9.6	9.9	0.3	3%	11.6	11.8	0.2	2%	14.2	14.3	0.1	1%
Below Normal (13%)	17.0	16.9	-0.1	0%	13.5	13.5	0.0	0%	9.5	9.4	0	0%	8.7	9.2	0.4	5%	11.0	11.4	0.3	3%	13.8	14.0	0.2	1%
Dry (24%)	16.9	16.9	0.0	0%	13.5	13.5	0.0	0%	9.9	9.9	0	0%	8.5	9.0	0.5	6%	11.1	11.5	0.4	4%	13.7	14.0	0.3	2%
Critical (15%)	17.0	16.9	-0.1	0%	13.3	13.3	0.0	0%	9.5	9.4	0	0%	8.3	8.9	0.6	7%	11.0	11.4	0.5	4%	14.1	14.4	0.3	2%

Statistic	Monthly Temperature (Deg-C)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
<b>Probability of Exceedance<sup>a</sup></b>																								
10%	16.2	16.4	0.2	1%	18.4	18.5	0.1	1%	20.8	21.0	0	1%	22.8	22.6	-0.2	-1%	21.9	22.0	0.0	0%	20.6	20.6	0.0	0%
20%	16.1	16.2	0.1	1%	18.1	18.2	0.1	1%	20.5	20.6	0	0%	22.4	22.2	-0.2	-1%	21.5	21.5	0.0	0%	20.2	20.3	0.0	0%
30%	15.8	15.9	0.1	1%	17.9	18.1	0.2	1%	20.1	20.2	0	1%	22.0	21.9	-0.1	-1%	21.2	21.2	0.0	0%	20.1	20.0	0.0	0%
40%	15.5	15.6	0.1	1%	17.7	17.9	0.2	1%	19.9	20.0	0	1%	21.5	21.4	0.0	0%	20.9	21.0	0.1	0%	19.8	19.8	0.0	0%
50%	15.3	15.5	0.2	1%	17.6	17.7	0.2	1%	19.6	19.7	0	0%	21.3	21.2	-0.1	0%	20.7	20.8	0.1	0%	19.5	19.5	0.0	0%
60%	15.1	15.3	0.2	1%	17.4	17.6	0.2	1%	19.5	19.6	0	1%	21.2	21.1	-0.1	0%	20.6	20.7	0.1	0%	19.3	19.3	0.0	0%
70%	14.9	15.1	0.1	1%	17.2	17.4	0.3	1%	19.2	19.4	0	1%	20.9	20.7	-0.1	-1%	20.5	20.4	-0.1	0%	19.2	19.1	0.0	0%
80%	14.6	14.8	0.2	1%	16.9	17.2	0.3	2%	19.0	19.1	0	1%	20.5	20.5	-0.1	0%	20.3	20.4	0.1	0%	19.0	19.0	0.0	0%
90%	14.3	14.6	0.3	2%	16.7	16.9	0.2	1%	18.6	18.7	0	1%	20.2	20.2	0.0	0%	20.0	20.0	0.0	0%	18.6	18.6	0.0	0%
<b>Long Term Full Simulation Period<sup>b</sup></b>	15.3	15.5	0.2	1%	17.5	17.7	0.2	1%	19.7	19.8	0	1%	21.4	21.4	-0.1	0%	20.9	20.9	0.0	0%	19.6	19.6	0.0	0%
<b>Water Year Types<sup>c</sup></b>																								
Wet (32%)	15.3	15.4	0.1	1%	17.9	17.9	0.0	0%	19.9	20.0	0	0%	21.8	21.8	0.0	0%	21.4	21.5	0.1	0%	20.1	20.0	0.0	0%
Above Normal (16%)	15.3	15.5	0.2	1%	17.7	17.9	0.2	1%	20.0	20.2	0	1%	21.3	21.2	0.0	0%	20.6	20.6	0.1	0%	19.5	19.5	0.0	0%
Below Normal (13%)	15.7	15.9	0.2	2%	17.2	17.5	0.3	2%	19.5	19.7	0	1%	21.3	21.1	-0.2	-1%	20.6	20.6	0.0	0%	19.4	19.4	0.0	0%
Dry (24%)	15.3	15.5	0.2	1%	17.4	17.7	0.3	2%	19.8	19.9	0	1%	21.4	21.1	-0.2	-1%	20.7	20.7	0.0	0%	19.5	19.4	0.0	0%
Critical (15%)	14.9	15.2	0.3	2%	17.0	17.3	0.3	2%	18.9	18.9	0	0%	21.2	21.1	-0.1	0%	20.7	20.7	-0.1	0%	19.1	19.0	-0.1	0%

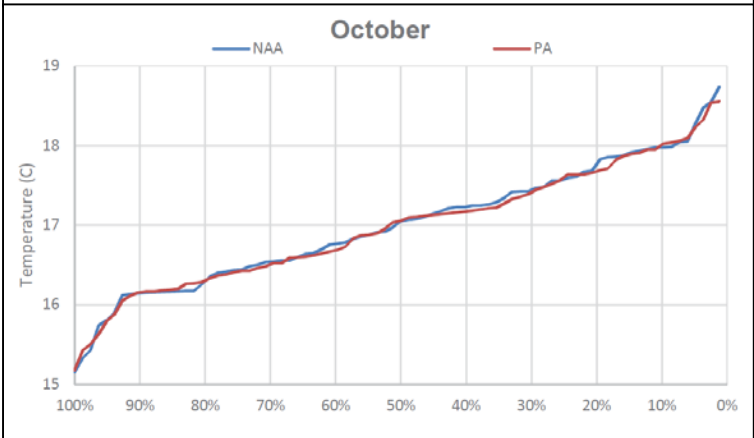
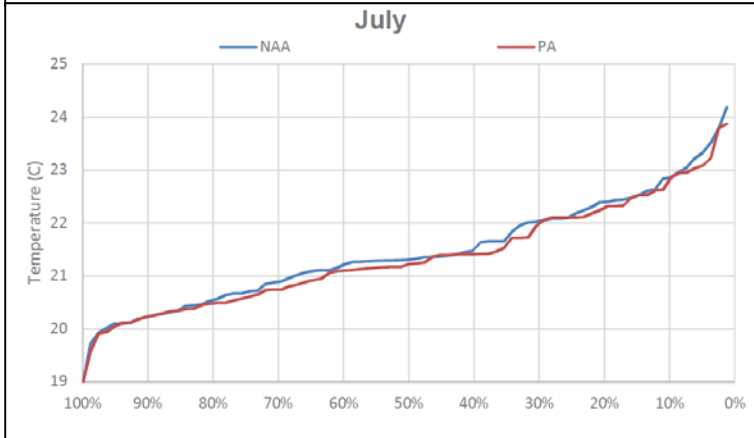
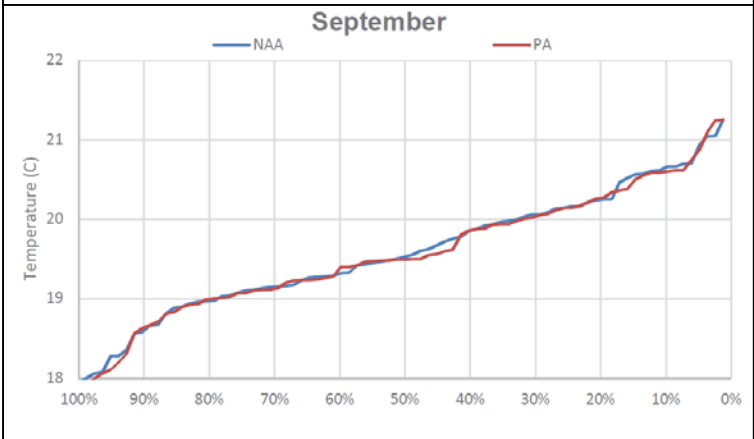
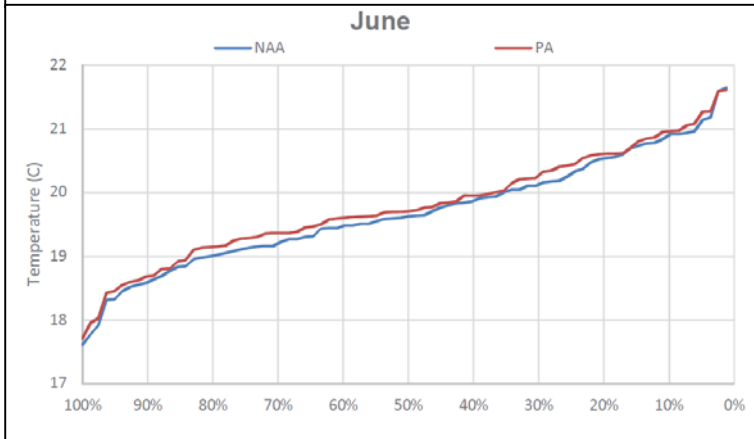
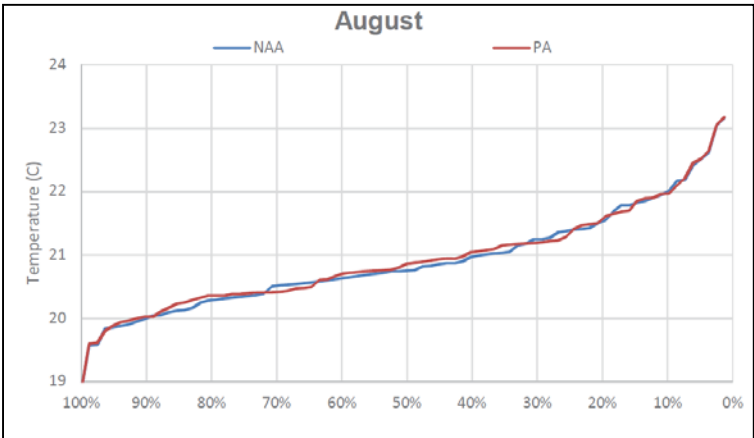
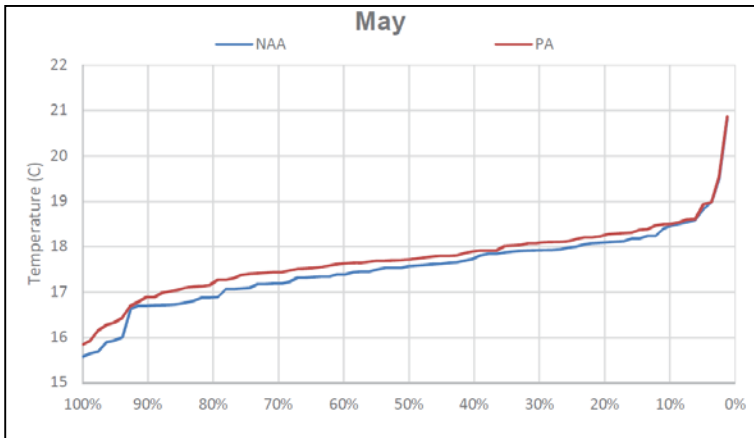
a Exceedance probability is defined as the probability a given value will be exceeded in any one year.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

# San Joaquin River near Stockton DWSC, Monthly Temperature



Source: Biological Assessment, Appendix 5B, Figure 5.B.5.43-1

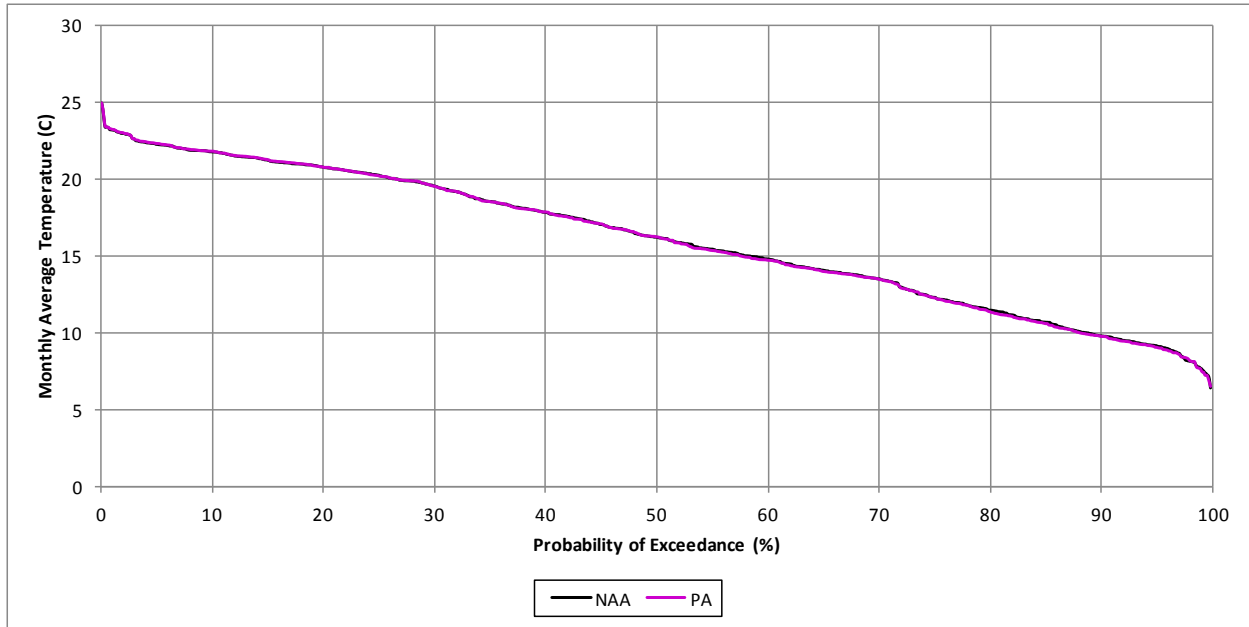


Figure 1. Middle River at Middle River Monthly Average Temperature for Period of Record WY1922-2002.

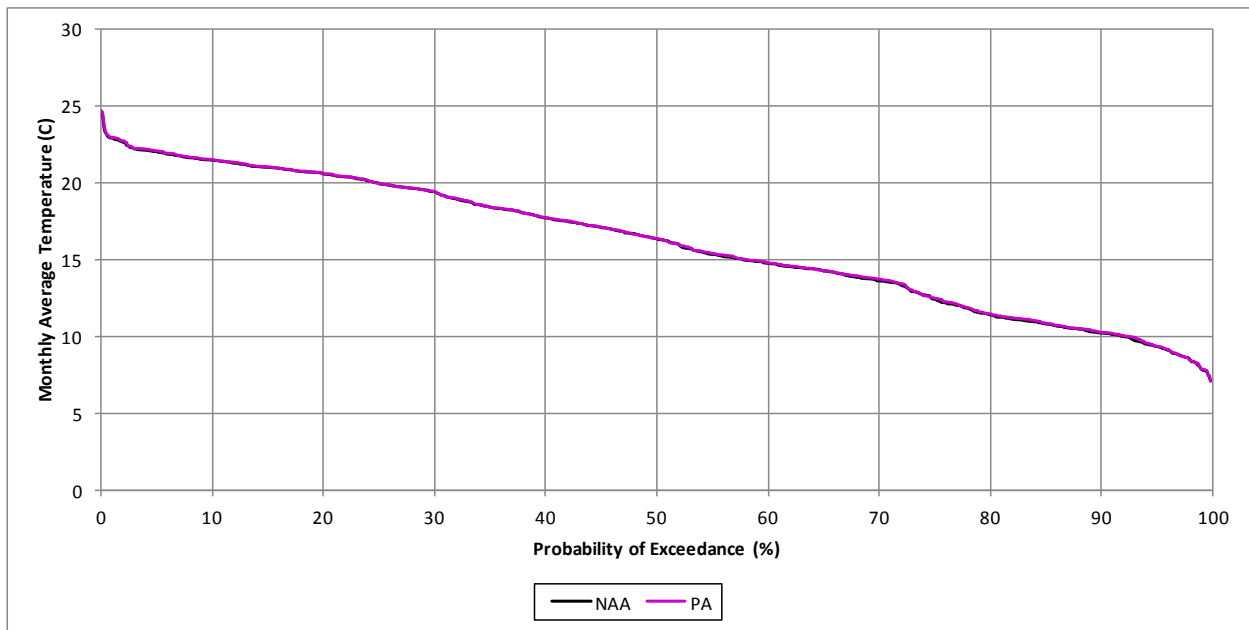


Figure 2. Middle River at Bacon Island Monthly Average Temperature for Period of Record WY1922-2002.

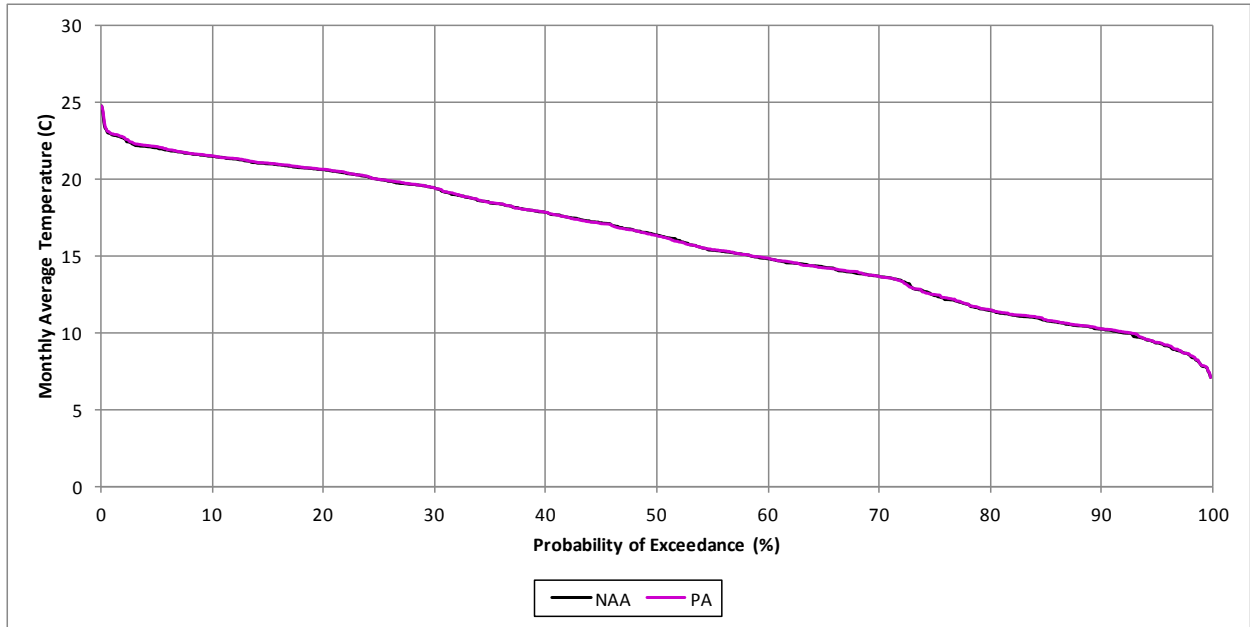


Figure 3. Victoria Canal near Bryon Monthly Average Temperature for Period of Record WY1922-2002.

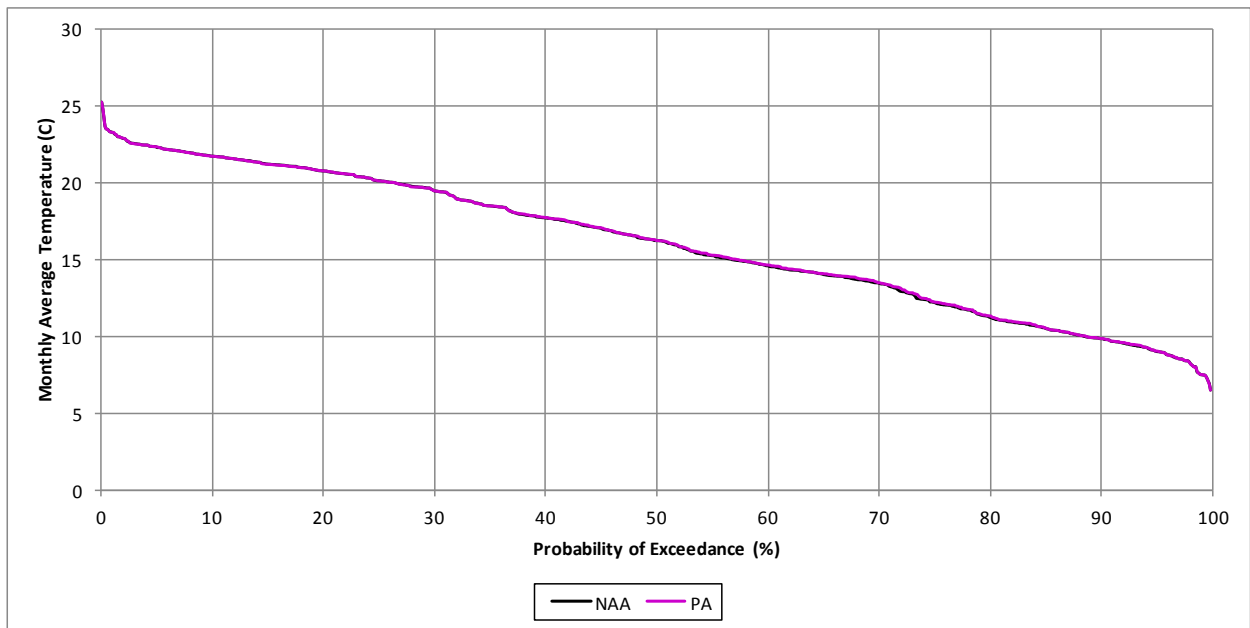


Figure 4. Old River at Holland Cut Monthly Average Temperature for Period of Record WY1922-2002.

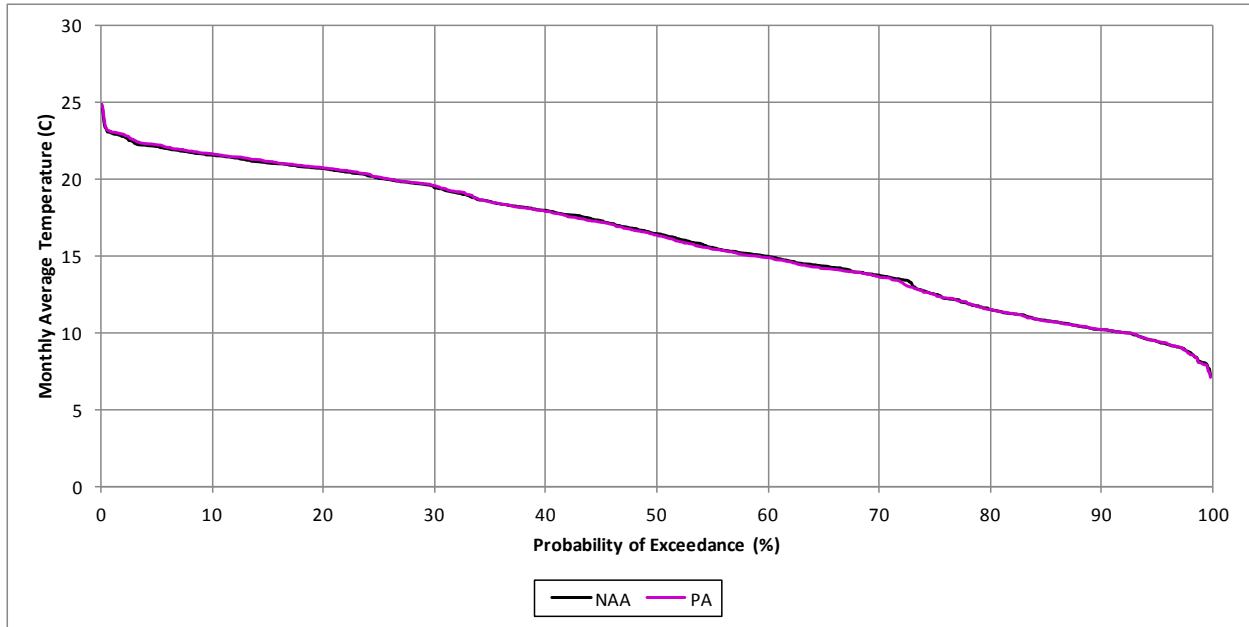


Figure 5. Old River at Clifton Court Ferry Monthly Average Temperature for Period of Record WY1922-2002.