Environmental Sciences

Exponent®

Report on the Effects of the California WaterFix Project on the City of Antioch

Exhibit Antioch-202

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Prepared for

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August 31, 2016

1405064.000 - 0539

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Acronyms and Abbreviations

AMMP	Adaptive Management and Monitoring Program
BA	biological assessment
BDCP	Bay Delta Conservation Plan
BiOp	biological opinion
CCWD	Contra Costa Water District
CDEC	California Data Exchange Center
cfs	cubic feet per second
CVP	Central Valley Project
CWF	California WaterFix
D-1641	SWRCB Water Rights Decision D-1641
Delta	California Sacramento-San Joaquin Delta
DSM	Delta Simulation Model
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
EC	electrical conductivity
ECCID	East Contra Costa Irrigation District
EIR	environmental impact report
EIS	environmental impact statement
FEIR	final environmental impact report
HHT	higher high tide
M&I	municipal and industrial
MAF	million acre feet
NAA	no action alternative
NDD	North Delta diversion
NMFS	National Marine Fisheries Service
POD	point of diversion
PORD	point of rediversion
PP#1	Contra Costa Canal at Pumping Plant #1
RDEIR	recirculated draft environmental impact report
Reclamation	U.S. Bureau of Reclamation
SDEIS	supplemental draft environmental impact statement
SWP	State Water Project
SWRCB	California State Water Resources Control Board
TUCP	Temporary Urgency Change Petition
USFWS	U.S. Fish and Wildlife Service
WaterFix	California WaterFix Project
WQO	water quality objective
WY	water year

1. Qualifications

My name is Susan Paulsen and I am a Registered Professional Civil Engineer in the State of California (License # 66554). My educational background includes a Bachelor of Science in Civil Engineering with Honors from Stanford University (1991), a Master of Science in Civil Engineering from the California Institute of Technology ("Caltech") (1993), and a Doctor of Philosophy (Ph.D.) in Environmental Engineering Science, also from Caltech (1997). My education included coursework at both undergraduate and graduate levels on fluid mechanics, aquatic chemistry, surface and groundwater flows, and hydrology, and I served as a teaching assistant for courses in fluid mechanics and hydrologic transport processes. A copy of my *curriculum vitae* is included as Exhibit Antioch-201.

My Ph.D. thesis was entitled, "A Study of the Mixing of Natural Flows Using ICP-MS and the Elemental Composition of Waters," and the major part of my Ph.D. research involved a study of the mixing of waters in the Sacramento-San Joaquin Bay-Delta (the Delta). I collected composite water samples at multiple locations within the Delta and used the elemental "fingerprints" of the three primary inflow sources (the Sacramento River, the San Joaquin River, and the Bay at Martinez), together with the elemental "fingerprints" of water collected at two interior Delta locations (Clifton Court Forebay and Franks Tract) and a simple mathematical model, to establish the patterns of mixing and distribution of source flows within the Delta during the 1996–1997 time period. I also directed model studies to use the chemical source fingerprinting to validate the volumetric fingerprinting simulations using Delta models (including the Fischer Delta Model (FDM) and the Delta Simulation Model (DSM)).

I currently am a Principal and Director of the Environmental and Earth Sciences practice of Exponent, Inc. ("Exponent"). Prior to that, I was the President of Flow Science Incorporated in Pasadena, California, where I worked for 20 years, first as a consultant (1994–1997) and then as an employee in various positions, including President (1997–2014). I have 25 years of experience with projects involving hydrology, hydrogeology, hydrodynamics, aquatic chemistry, and the environmental fate of a range of constituents. I have knowledge of California water supply issues, including expertise in California's Bay-Delta estuary. My expertise includes designing and implementing field and modeling studies to evaluate groundwater and surface water flows and contaminant fate and transport. I have designed studies using one-dimensional hydrodynamic models, three-dimensional computational fluid dynamics models, longitudinal dispersion models, and Monte Carlo stochastic models, and I have directed modeling studies and utilized the results of numerical modeling to evaluate surface and groundwater flows.

I have designed and implemented field studies in reservoir, river, estuarine, and ocean environments using dye and elemental tracers to evaluate the impact of pollutant releases and treated wastewater, thermal, and agricultural discharges on receiving waters and drinking-water intakes. I have also designed and managed modeling studies to evaluate transport and mixing, including the siting and design of diffusers, the water quality impacts of storm water runoff, irrigation, wastewater and industrial process water treatment facilities, desalination brines and cooling water discharges, and groundwater flows. I have designed and directed numerous field studies within the Delta using both elemental and dye tracers, and I have designed and directed numerous surface water modeling studies within the Delta.

2. Introduction and Background

In October 2015, the California State Water Resources Control Board (SWRCB) issued a Notice of Petition that the California Department of Water Resources (DWR) and U.S. Bureau of Reclamation's (Reclamation) were seeking to add three new points of water diversion/rediversion (POD and PORD, respectively) to their water rights permits as part of the California WaterFix Project (WaterFix) implementation (Exhibit Antioch-203). The WaterFix Project, as described in the Recirculated Draft Environmental Impact Review (RDEIR)/Supplemental Draft Environmental Impact Statement (SDEIS), is identified as Alternative 4A, the California Environmental Quality Act (CEQA) preferred alternative. The WaterFix Project includes water conveyance facilities consisting of three new water diversion intakes along the Sacramento River between Clarksburg and Courtland (also referred to as the North Delta Diversions, NDD) and two twin concrete tunnels (30 miles long, 40 ft in diameter) to convey water from the new PODs to the existing pumping facilities near Tracy (Antioch-203).

DWR and Reclamation have stated in their petition and WaterFix Project documents that diversions from the Sacramento River will be "greatest" during wetter periods and "lowest" during drier periods (Exhibit SWRCB-1). The petition indicates that approximately half of the total Delta diversions will occur at the new Sacramento River diversion points, while the other half will remain at the existing pumping stations in the South Delta (i.e., Banks Pumping Plant and Jones Pumping Plant) (Exhibit SWRCB-1; Exhibit Antioch-203). DWR and Reclamation generally state that the construction of the water conveyance tunnels and new points of diversion will afford the agencies greater flexibility in managing and transporting water to various pumping stations and users (Exhibit SWRCB-1; Exhibit Antioch-203). DWR submitted an environmental impact report (EIR) for the Bay Delta Conservation Plan (BDCP) in December 2013 and issued an RDEIR/SDEIS for the WaterFix Project in July 2015; the agency has not yet submitted a final EIR for WaterFix (Exhibit SWRCB-3).

I was retained by the City of Antioch (the City) to assist in preparing comments on DWR's and Reclamation's joint petition to amend their existing water rights permits to allow new water diversions under the State Water Project (SWP) and Central Valley Project (CVP) (collectively, the Projects). Specifically, I evaluated whether the proposed diversions will have an impact on the supply and quality of water available to Antioch, which uses fresh water from the Delta for potable municipal and industrial (M&I) supply. This report presents my analysis and technical comments on the impact of the WaterFix Project on the supply of fresh water available to Antioch. In conducting my work, I evaluated model runs performed by DWR to describe the proposed WaterFix operations under various diversion scenarios to determine if the quality or quantity of water diverted by the City will be impacted. I also directed modeling using DWR's model input files to obtain additional model output not provided by DWR, and I reviewed DWR's assessment of the proposed project to determine if their evaluation sufficiently characterizes the expected water quality impacts on the City, the operations of the proposed project, anticipated compliance with water quality objectives, and other factors.

The City is located in Contra Costa County, California, in the East Bay region of the San Francisco Bay Area, along the San Joaquin River channel in the western Sacramento-San Joaquin Delta (Figure 1).The background of the City's water rights, supply, demands, and operations are set forth within the Testimony of Ron Bernal (Exhibit Antioch-100). I am also very familiar with the City's water rights, supply, demands, and operations, as I have worked with the City for nearly 10 years regarding these matters. Instead of duplicating Mr. Bernal's testimony in my written statement, I confirm that I have reviewed his testimony and am familiar with it and have relied on it in part in forming the opinions I am expressing.

This testimony presents six Opinions in response to the SWRCB's Notice of Petition: Water was historically fresh at Antioch (Opinion 1); DWR's evaluation of the proposed WaterFix Project is inadequate (Opinion 2); WaterFix will result in substantial changes in Delta hydrodynamics and degradation of water quality at Antioch (Opinion 3); the water quality degradation caused by WaterFix will impact the City's operations (Opinion 4); compliance with water quality standards is likely to become more challenging in the future, and WaterFix will degrade water quality at the City's intake (Opinion 5); and the information provided in the petition is insufficient for assessing the expected impacts of the WaterFix Project, but it appears that significant water quality degradation can be expected to occur (Opinion 6). The bases for these opinions and supporting documentation are provided herein.

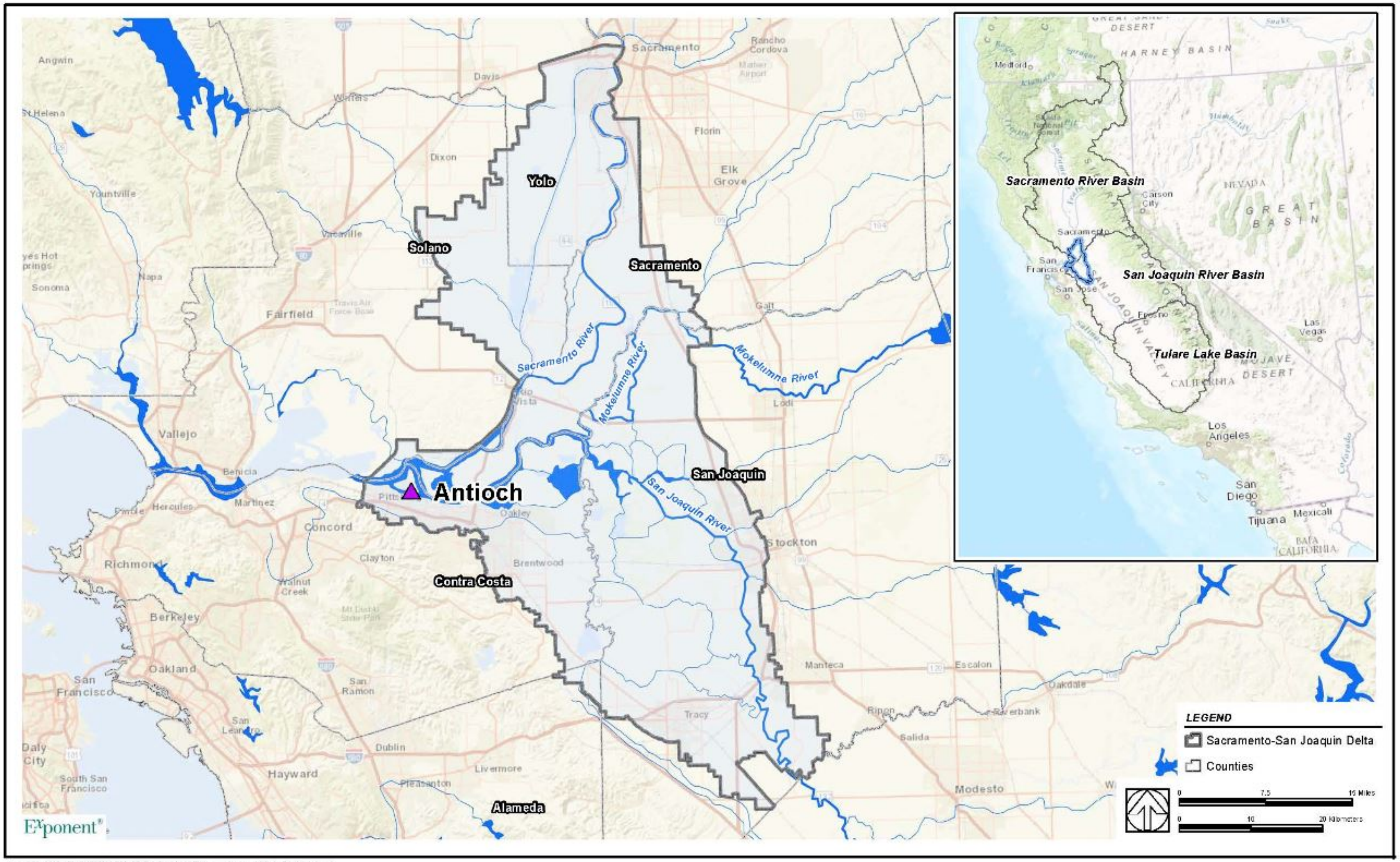

Figure 1 Location of the City of Antioch in the San Francisco Bay area, California.

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3. Methods

3.1. DSM2 Modeling and Volumetric Fingerprinting

DWR used the Delta Simulation Model II (DSM2) to simulate hydrodynamics and water quality throughout the Delta for a range of model conditions and operational scenarios. The DSM2 model has three separate components: HYDRO, QUAL, and PTM. HYDRO simulates flows in the channels defined in the DSM2 grid, stage (water surface elevation), and tidal forcing at the downstream model boundary (Martinez). QUAL simulates the concentrations of conservative (i.e., no decay or growth) variables, such as EC (electrical conductivity, a measure of salinity), given the flows in the Delta channels simulated by HYDRO. Although QUAL can simulate non-conservative variables, such as temperature and turbidity, results for non-conservative variables are not considered in this testimony. The particle tracking model (PTM) simulates mixing and transport of neutrally buoyant (suspended) particles based on the channel geometry and tidal flows simulated by HYDRO. The model results (model output) provided by DWR in May 2016 include hydrodynamic and water quality information.

In addition to hydrodynamics and water quality modules, the DSM2 model can be used to perform “volumetric fingerprinting” to track inflows to the Delta throughout the model domain. Volumetric fingerprinting can be used to “tag” inflows to the Delta and to determine the source of water within the estuary. Because the model input and output files provided to the public by DWR did not include volumetric fingerprinting results, Exponent used the model input files provided by DWR and the DSM2 model to perform volumetric fingerprinting to determine the location and time that flows from various sources entered the Delta; this analysis was performed for each of the Project scenarios and for the existing condition model run described below. The DSM2 modules used for the analyses and fingerprinting presented in this report include HYDRO and QUAL. Exponent’s fingerprinting results are described in Opinion 3.

DWR released new modeling for the WaterFix Project in May 2016. DWR had previously released DSM2 modeling analyses and results for the existing (no project) condition and for the Project (or prior iterations of the Project) in association with the 2013 Draft EIR/EIS, the 2015 RDEIR/SDEIS, the 2016 Draft Biological Assessment (BA), and the 2016 final EIR (FEIR). The modeling files were obtained from:

- 2013 EIR/EIS: Received (date unknown) from DWR, including files for scenario EBC2
- 2015 RDEIR/SDEIS (updates and sensitivity files): Received September 9, 2015 from DWR (B.G. Heiland)
- EBC1 model run: Downloaded September 30, 2015 from DWR (B.G. Heiland)
- 2016 Draft BA: Downloaded February 2, 2016 from Reclamation (Michelle Banonis)
- 2016 FEIR: Downloaded March 4, 2016 from DWR (B.G. Heiland) (note that only the model runs were released; the FEIR that presumably relies upon these model runs has not yet been released)

- 2016 WaterFix petition: Downloaded May 28, 2016 from https://ftp.waterboards.ca.gov/

The DSM2 model produces data on 15-minute intervals. The time period modeled in DSM2 for most WaterFix and BDCP analyses spans from water year (WY) 1975–WY 1991; however, the model results from WY 1975 are considered model "spin-up" time and are excluded from analyses. The analyses in this report are based on the 16-year record from WY 1976–WY 1991. The scenarios evaluated in the May 2016 modeling performed in support of the WaterFix petition include operational scenarios H3 and H4, Boundary 1, Boundary 2, and the No Action Alternative (NAA). Descriptions of these various scenarios can be found in Exhibit Antioch-204, which was previously submitted by the DWR as Exhibit DWR-5. In addition, existing conditions were evaluated using scenario EBC2.

3.2. Salinity and Bromide Calculations

The salinity of water in the Delta has historically been expressed as electrical conductivity (EC), total dissolved solids (TDS), or chloride. Many salinity measurements in the Delta are made using EC, and EC is widely used as a surrogate for salinity (Exhibit Antioch-205). Guivetchi (1986) derived linear relationships between EC, TDS, and chloride for various locations in the Delta and generated mathematical equations that can be used to convert one type of salinity measurement to another. The DSM2 model provides salinity as EC which is converted to chloride using these relationships.[1] For the City, the relationship used to convert EC to chloride for normal water years was as follows: chloride [mg/L] = -70.06 + (0.31858*EC [μmhos/cm]). Thus, at the City's intake location, a chloride concentration of 250 mg/L (ppm) is assumed to correspond to an EC of 976 µS/cm.

The EC (salinity) of freshwater inflows to the Delta is lower than that of sea water or water from San Francisco Bay. In general, the salinity of the Sacramento River is low, about 100 mg/L TDS; the salinity of water in the eastside streams is also low, typically less than 100 mg/L TDS.[2] For example, in 2015, averaged measured EC in the Sacramento River at Freeport was 168 µS/cm (equivalent to TDS of 103 mg/L using the method of Guivetchi 1986) and ranged from approximately 109 to 281 µS/cm (TDS from 72 to 163 mg/L). Average EC in the San Joaquin River at Vernalis was 595 µS/cm (343 mg/L TDS), ranging from 99 to 1323 µS/cm (48 to 776 mg/L TDS), and average EC at Martinez (downstream boundary of Delta) was 26,384 µS/cm (17,882 mg/L TDS), ranging from 11,501 to 47,204 µS/cm (7440 to 32,490 mg/L TDS) (CDEC, data accessed online 1-6-15, Figure 4-8). By contrast, the salinity of seawater is approximately 50,000 µS/cm (35,000 mg/L TDS).

In addition to conversions between EC, TDS, and chloride, there is an established relationship between chloride and bromide in the Delta, both of which are present in seawater. DWR has

[1] See http://www.water.ca.gov/suisun/facts/salin/index.cfm for additional details.

[2] Data obtained and reviewed from CDEC, accessed online at http://cdec.water.ca.gov/./

stated that the bromide concentration can be computed as bromide [mg/L] = 0.0035*Cl [mg/L][3] (Exhibit Antioch-206). Thus, a chloride concentration of 250 mg/L is equivalent to a bromide concentration of 0.88 mg/L (880 µg/L); chloride concentrations of 150 mg/L and 100 mg/L are equivalent to bromide concentrations of about 0.53 mg/L (530 µg/L) and 0.35 mg/L (350 µg/L), respectively.

3.3. D-1641 Water Quality Objectives

DSM2 results were used to evaluate the "compliance" of the different modeled scenarios and existing conditions with applicable water quality objectives. SWRCB Water Right Decision 1641 (D-1641) (Exhibit SWRCB-21) establishes water quality objectives (WQOs) in the Delta for various beneficial uses. As discussed in Opinion 5, DSM2 results were used to evaluate the frequency with which the different modeled scenarios and baseline conditions were consistent with the D-1641 WQOs for M&I beneficial uses.

D-1641 uses two chloride thresholds to define WQOs for M&I beneficial uses at various locations as shown in Table 1. Compliance was evaluated for each modeled scenario at both Contra Costa Canal at Pumping Plant #1 (PP#1) and at the City for the 150 mg/L threshold and at PP#1 for the 250 mg/L threshold. Results are discussed in Opinion 5.

D-1641 also includes a limitation on exports that is expressed in terms of the ratio of total exports out of the Delta (E) to total inflows to the Delta (I). The combined export rate (E) for this objective is defined in D-1641 as the Clifton Court Forebay inflow rate (minus Byron-Bethany Irrigation District diversions from Clifton Court Forebay) plus the export rate of the Tracy pumping plant and is calculated as a three-day running average.

The total inflow (I) to the Delta is defined in D-1641 as the sum of mean daily flows from the Sacramento River inflows at Freeport, San Joaquin River inflows at Vernalis, the eastside streams (Mokelumne, Cosumnes, and Calaveras Rivers), Sacramento Regional Treatment Plant average daily discharge from the previous week, the mean daily flow from the Yolo Bypass for the previous day, and other miscellaneous flows (combined mean daily flow from Bear Creek, Dry Creek, Stockton Diverting Canal, French Camp Slough, March Creek, and Morrison Creek). Delta inflows are summed and evaluated as a 14-day running average.

[3] In Exhibit Antioch-206, DWR cites the source of this equation as Exhibit Antioch-229. The conversion equation presented in Exhibit Antioch-229 however is different from that stated above. Exhibit Antioch-229 shows the relationship of bromide [mg/L] = 0.00341*Cl[mg/L]+0.033.

Table 1. Water quality objectives (WQOs) for municipal and industrial beneficial uses as specified in D-1641.

Compliance Location	Parameter	Description	Water Year Type	Time Period	Value
Contra Costa Canal at Pumping Plant #1 **or** San Joaquin River at Antioch Water Works Intake	Chloride (Cl-)	Maximum mean daily 150 mg/L Cl- for at least the number of days shown during the Calendar Year [in the "Value" column]. Must be provided in intervals of not less than two weeks duration.	W	--	240 days
			AN	--	190 days
			BN	--	175 days
			D	--	165 days
			C	--	155 days
Contra Costa Canal at Pumping Plant #1, **and** West Canal at Mouth of Clifton Court Forebay, **and** Delta-Mendota Canal at Tracy Pumping Plant, **and** Baker Slough at North Bay Aqueduct Intake, **and** Cache Slough at City of Vallejo Intake	Chloride (Cl-)	Maximum mean daily (mg/L)	All	Oct-Sep	250 mg/L Cl-

For the purposes of this analysis, I calculated exports and inflows to the Delta from DSM2 model results with the following minor variations from the method specified in D-1641: flows from Sacramento Regional Wastewater Treatment Plant and miscellaneous flows were omitted, as these flows are small relative to the other flows specified in D-1641 and are not expected to change the analysis results significantly. Delta inflows were calculated as 14-day running averages, while Delta exports were calculated as three-day running averages. D-1641 limits Delta exports to 35% of Delta inflow between February and June (i.e., E/I < 0.35 from February-June) and to 65% of Delta inflow between July and January (i.e., E/I < 0.65 from July-January). There are some exceptions to these general rules[4] that were not considered in this analysis.

Because some WaterFix Project scenarios will increase the total amount of water exported from the Delta, the E/I ratio will change for these scenarios. Consistent with D-1641's definition of "E" as total exports and "I" as total inflows, I evaluated the E/I ratio for the WaterFix scenarios as:

$$\left[\frac{E}{I}\right]_{D-1641} = \frac{Banks + Jones + NDD\ Exports}{Sacramento + San\ Joaquin + Cosumnes + Calaveras + Mokelumne + Yolo\ inflows} \qquad \text{Eqn. 1}$$

However, the Draft Biological Assessment (Exhibit SVWU-1) states that, "The D-1641 export/inflow (E/I) ratio calculation was largely designed to protect fish from south Delta entrainment. For the PA [Preferred Alternative], Reclamation and DWR propose that the NDD be excluded from the E/I ratio calculation. In other words, Sacramento River inflow is defined as flows downstream of the NDD and only south Delta exports are included for the export component of the criteria."[5] By this proposed method of calculation, both total inflows and total exports would be reduced by the volume of water exported from the NDD:

$$\left[\frac{E}{I}\right]_{CWF,modified} = \frac{Banks + Jones\ Exports}{(Sacramento - NDD\ Exports) + San\ Joaquin + Cosumnes + Calaveras + Mokelumne + Yolo\ inflows} \qquad \text{Eqn. 2}$$

From a mathematical perspective, subtracting the NDD exports from both the numerator and denominator of equation (1) to produce equation (2) reduces the calculated E/I ratio, such that the E/I ratio is less restrictive under the new proposed modified calculation method. Because I am not aware of whether this modified calculation method would constitute a change in water quality standards, I calculated the E/I ratio using both calculation methods and using the DSM2 model output provided by DWR; see Opinion 5.

3.4. Water Year Type Classifications

Hydrology in the Delta varies from year to year. Water years in the Delta, defined as October through September of the following year, are classified as wet, above normal, below normal, dry, or critical. DWR determines the water year type by calculating a water year index number,

[4] See Exhibit SWRCB-21, pp. 186–187.

[5] See Exhibit SVWU-1, pp. 3–80.

which accounts for both the hydrology of the current year and the previous year's index.[6]. By this classification system, the water years modeled in DSM2 by DWR fall into the following categories:

- Critical: 1976, 1977, 1988, 1990, 1991
- Dry: 1981, 1985, 1987, 1989
- Below Normal: 1979
- Above Normal: 1978, 1980
- Wet: 1982, 1983, 1984, 1986

Because there is only one Below Normal water year in the modeled record, Exponent combined results for the Below Normal year with model results for Above Normal water years for the purposes of analyzing the WaterFix model runs; the water year type for water years 1978–1980 is referred to from here forward as "Normal." In some analyses, data are averaged by month or by water year type. This is done by aggregating data from those specific months or water year types and calculating an average. For example, the daily average chloride concentration during March of dry water years was calculated by sorting the DSM2 model results into bins such that the simulated salinity values for each day in March from years 1981, 1985, 1987, and 1989 were grouped and could then be averaged.

In addition, we relied upon DWR's water year classifications for the entire period of record, as summarized in Exhibit Antioch-208.

3.5. Water Usability at Antioch's Intake

DWR entered into an Agreement with the City in 1968 to compensate the City for water it must purchase as a result of declining water quality at its intake as caused by the SWP; that agreement defined water as "usable" when the chloride concentration at the City's intake on the San Joaquin River channel is less than 250 mg/L as measured at slack current after higher high tide (HHT) (Exhibit Antioch-101; Exhibit Antioch-102). When the term of the 1968 Agreement was amended in 2013 through September 30, 2028, the Amendment clarified that "slack current after higher high tide" occurs approximately two hours after HHT. To calculate usability at the City's intake, I used DWR's model results to determine the EC level (converted to chloride concentration using the relationship in Section 3.2) at two hours after HHT for each day in the simulation period. Results are described in Section 8.

3.6. Analysis of Antioch's Intake Operations

The modeled salinity data from DSM2 at Antioch's intake were evaluated to determine the effects on the City's water treatment operations, and ultimately how many fewer days the City is predicted to be able to use water at its intake under the B1 scenario compared to EBC2 and NAA. As described in Section 3.5 above, the 1968 Agreement defines usable water days at Antioch, but the City operates its intake and water treatment operations according to real-time

[6] Water year classifications from CDEC, accessed at http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST, and presented as Exhibit Antioch-208.

salinity measurements (not just two hours after HHT). For this analysis, it was assumed that the City pumps San Joaquin River water at their intake when chloride concentrations are below 250 mg/L, and that the City's intake can be operated on hourly time steps; in reality their operations are more complex, but for the sake of this analysis this assumption is appropriate. The 15-minute DSM2 data were averaged on an hourly basis and compared to the threshold value. The number of hourly averaged data points below the 250 mg/L chloride threshold were summed, converted to days (i.e., 24 one-hour intervals below the threshold became one "equivalent" day), and averaged by water year type.

3.7. Cost Calculations

It was assumed that the City purchases 100% of its water supply from Contra Costa Water District (CCWD) when water at its intake has a chloride concentration above 250 mg/L. When chloride levels are between 100 and 250 mg/L at the City's intake, it was assumed that the City's supply would consist of 50% water from the City's intake and 50% water purchased from CCWD. Finally, it was assumed that the City's entire supply would be pumped from the City's intake when chloride levels at the City's intake are less than 100 mg/L. In reality, the City's operations are more complex; however, these assumptions generally reflect City's operations. As mentioned above, the City has the ability to make real-time decisions with their operations, reacting to fluctuations in salinity at their intake. Therefore hourly averaged DSM2 salinity data (as described in Section 3.6), were evaluated with regards to the 100 mg/L and 250 mg/L chloride thresholds. The amount of time above or below compliance was converted to equivalent days per water year.

The present-value calculation relies on the following assumptions:

- The base cost of purchasing water from CCWD in 2015 (C_{2015}) was provided by the City and was $2,300 per million gallons (i.e., $766 per acre-foot), which was the average amount paid in 2015.
- The cost of water is assumed to increase 3% annually. This uniform rate was used to calculate the present value of the cost of purchasing water over a 50-year period.
- Because a city may invest in other capital projects, a municipal bond rate was used as the discount rate (or interest rate) in this calculation. Municipal bond rates vary depending on issuer credit rating and maturity range of the bond. Currently, these values range from about 2.0% to 3.5%. A 3.0% discount rate was used, which represents the yield for a 30-year national municipal bond.[7]
- The annual water demand for the City is assumed to remain constant at 5,000 million gallons (MG).[8]

[7] Bond yield quote from http://www.bloomberg.com/markets/rates-bonds/government-bonds/us retrieved on December 29, 2015.

[8] Based on average water usage provided by the City for years 2013, 2014, and 2015 (through November 2015).

- Water quality impacts were used as the basis for the cost computations as follows:
  - The number of days that water must be purchased by the City under each operational scenario (call this value D) is equivalent to the number of days the average chloride concentration exceeds 250 mg/L, and 0.5 times the number of days the average chloride concentration falls between 100 and 250 mg/L.[9]
  - The cost for water in the year 2028 (C_{2028}), the first year the WaterFix Project is assumed to be operational, is calculated as $C_{2028} = D \times (C_{2015} \times 1.03^{13})$.
  - Estimated costs are calculated for a 50-year period beginning in 2028. The 2028 value of the cost of water (PV_{2028}) was calculated as: [10] $PV_{2028} = 50 \times C_{2028} \div 1.03$.
  - PV_{2028} for scenarios EBC2, NAA, and Boundary 1 was discounted to present (2016) value as $PV_{2016} = PV_{2028,diff} \div 1.03^{12}$.
- Because the City's current Agreement with DWR can be terminated as soon as 2028, it is assumed that no reimbursement would be received by the City pursuant to this Agreement.

[9] DSM2 simulations performed by DWR for the period 1974–1991 provided salinity data at the City's intake at 15-minute intervals, which were converted to hourly average salinity values. The number of hours during which chloride levels exceeded 100 and 250 mg/L were summed for each water year of the 16-year period and converted to a total number of days to calculate the number of days per water year.

[10] Expression for present value of a geometric gradient where the geometric gradient factor (annual water rate increase) is equivalent to the discount rate.

3. Delta Hydrodynamics

The Sacramento-San Joaquin River Delta (Delta) is the transition zone between the San Francisco Bay and its watershed, which is a 16.3-million-hectare (62,900-square-mile) basin that occupies roughly 40% of California's land area (Antioch-209). The Delta is fed by fresh water from the Sacramento River and San Joaquin River basins and east-side streams and is connected to the San Francisco Bay through Suisun and San Pablo Bays (Figure 1). The Sacramento River and Yolo Bypass provide approximately 60% to 80% of total inflow to the Delta (depending on hydrologic year type), the San Joaquin River provides about 13% to 17% of total inflow, and the east-side streams, including the Calaveras, Cosumnes, and Mokelumne Rivers, constitute approximately 3% to 4% of total inflow (Exhibit Antioch-210; Exhibit Antioch-211).

The salinity of water within the Delta results from the balance of freshwater flows into the Delta and higher salinity water that enters the Delta from the west as a result of tidal action. At the western boundary of the Delta, water typically has salinity levels that are intermediate between freshwater and ocean water. The salinity at the western Delta boundary results from the mixing of saltwater that enters San Francisco Bay through the Golden Gate from the Pacific Ocean and freshwater flows both from the Delta and from stream and river flows that enter San Francisco Bay west of the Delta. Freshwater outflow from the Delta typically meets higher salinity water at an interface near Suisun Marsh; however, the location of this transitional zone is not fixed but rather fluctuates depending on freshwater flows and tidal action.

Salinity in the western Delta is also a function of both season and year type. Salinity levels in the western Delta are typically low in the winter and spring months, when river outflows are higher as a result of winter rains and spring snowmelt, and higher in summer and fall months. During wet years, the Delta is dominated by fresh water flows, and the saltwater-freshwater interface may be pushed into San Francisco Bay to the west of the Delta. During dry years, river flows are lower than in wet years, and the saltwater-freshwater interface may extend into the Delta.

Even if there was no freshwater inflow into the Delta, water would be present in the Delta as the bottom elevation of most Delta channels is below sea level—i.e., even if there were no freshwater flows into the system, water from San Francisco Bay would flow into the system, and water would be present. As noted by DWR,

> *"Because the Delta is open to the San Francisco Bay complex and the Pacific Ocean and its channels are below sea level, it never has a shortage of water. If the inflow from the Central Valley is insufficient to meet the consumptive needs of the Delta, saline water from the bay fills the Delta from the west. Thus, the local water supply problem in the Delta becomes one of poor water quality, not insufficient quantity."* (Exhibit Antioch-212)

Variations in hydrology also have a significant impact on the salinity and water quality of the Delta. Multiple drought periods have occurred over the last century and have served to decrease fresh water outflows and increase salinity intrusion farther east into the Delta. As discussed in Section 3.4, water years are classified by DWR as wet, above normal, below normal, dry, or critical. Water year indices and classifications for the entire 1906 to 2015 period are included in Exhibit Antioch-208.

The City's location in the Western Delta makes its intake in the San Joaquin River channel susceptible to seawater intrusion, especially during periods of low fresh water flows (e.g., drought years, fall months) and during flood tide conditions. The City operates its intake in the San Joaquin River channel in response to the water quality of the river, which is measured continuously. Typically the City diverts water from its intake during the winter and spring months when seasonal fresh water flows are higher and salinity is low, and the City generally purchases water during the summer and fall months when salinity at its intake increases. The City has the ability to operate its intake on an hourly basis and to turn its diversion on and off in response to changes in salinity during the course of a day.

4. Opinion 1: Water was historically fresh at Antioch.

DWR's testimony states that prior to the implementation of the SWP and CVP, salinity intruded "well into the interior of the Delta during the irrigation season" (Exhibit Antioch-213, reproducing DWR-53 pp. 14:3–4). Antioch-214 (reproducing DWR-301) includes figures showing seawater intrusion during the period of 1921–1943 (including some years, such as 1931, when salinity levels as high as 1,000 ppm chloride extended into the interior Delta) and during the period of 1944–1990 (when the 1,000 ppm chloride line extended less far into the Delta). DWR asserts that the "comparison of the two figures illustrates an incidental benefit to significant portions of the Delta provided by SWP/CVP reservoir storage releases" (Exhibit Antioch-213 p. 14:14–15). DWR further states that "historical salinity was at times greater than current conditions" (Exhibit Antioch-213 p. 15:1–2).

Because DWR does not discuss historical salinity conditions prior to 1921, DWR may leave the false impression that the Delta was historically a saline water body and that the CVP and SWP have served to improve water quality; however, the reality is not so simple, and it is important to establish the appropriate historical context for the current WaterFix proceedings. While the SWP and CVP do serve to introduce low salinity Sacramento River water into the South Delta and thereby reduce salinity levels in this portion of the Delta as compared to conditions in the 1920s and 1930s, the negative water quality impacts of the Projects on salinity in the Western Delta are more severe. As detailed below (and as acknowledged by DWR in its 1968 Agreement with the City), water quality in the western Delta and at the City's intake has declined as a result of the implementation of the State Water Resources Development System.

An abundance of evidence indicates that water in the Delta was predominantly fresh prior to the early 1900s, and water at the Antioch intake would have been fresh for most of the year. Salinity patterns within the Delta have changed markedly over time in response to changes in the configuration of the Delta and flows to the Delta. The Delta was naturally and historically a fresh water body, and the saltwater-freshwater interface intruded into the western Delta only during dry months of dry years; however, changes in flow patterns (including the diversion and storage of flows upstream of the Delta) and changes in the geomorphology of the Delta (including the channelization of the Delta and the loss of tidal marsh areas) between the late 1800s and the mid-1900s changed the salinity distribution within the Delta, resulting in the movement of the freshwater-saltwater interface farther inland into the Delta. The storage and diversion of Delta water under operations by the SWP and CVP have had a significant impact on the increasing salinity and water quality degradation in the Western Delta, including at the City's water intake.

After about 1917, water and land use practices changed salinity levels within the Delta from a principally fresh condition to a much more saline condition. Coincidentally, salinity levels began to be monitored by the California Department of Water Resources and its predecessor organizations (collectively referred to in this report as "DWR") in about 1920 (Exhibit Antioch-215). Historical measurements collected by DWR form the basis for the widespread (but inaccurate) belief that salinity levels observed after 1917 represented the historical or natural condition.

5.1. Water at Antioch's intake was generally fresh prior to the early 1900s.

Historical water quality conditions in the Western Delta have been characterized over a long period of time and in detail at the City, which is one of the oldest cities in northern California (incorporated in 1872). DWR (1960) assessed historical salinity conditions around the City in the early 1900s (Exhibit Antioch-215) and estimated that, under "natural" Delta conditions (i.e., without water management or water exports), water that was less than 350 ppm chloride would be available at the City approximately 85% to 90% of the time (Exhibit Antioch-215). Exhibit Antioch-215 estimated that in 1900, fresh water was available 80% of the time at the City and that the decline in fresh water availability from natural conditions was due to upstream diversions of the fresh water (Exhibit Antioch-215). DWR also estimated that by 1920, the availability of fresh water had decreased to approximately 70% due to an increase in the number of diversions that occurred between 1900 and 1920 (Exhibit Antioch-215).

Documentation from a 1920 water rights lawsuit filed by the City against an upstream irrigation district (*Town of Antioch v. Williams Irrigation District*) also describes the increased salinity conditions and saltwater intrusion the City experienced in the early 1900s (Exhibits Antioch-216; Antioch-231). In that lawsuit, the City claimed the diversion of water for irrigation upstream of the Delta caused an increase in the salinity of their water intake supply in the western Delta (Exhibit Antioch-216). Testimony from both the plaintiffs (the City) and defendants (irrigators) indicated that the City was able to pump fresh water from the San Joaquin River until at least 1915 but the water was often brackish at low tide or during summer and fall months (Exhibits Antioch-216; Antioch-231). Testimony from the City indicated that, prior to 1918, fresh water was available in the river during dry years and during the summer and fall months (Exhibit Antioch-106). The City recorded the concentration of salinity in the river in August or September from 1913 to 1917 and noted that the salinity more than doubled over the four-year period between 1913 and 1917 (66 ppm recorded in September 1913 [dry year]; 141.6 ppm recorded in September 1917 [wet year]) (Exhibit Antioch-231). Additional detail can be found in Antioch (2010) (Exhibit Antioch-231).

Other historical records confirm that the Delta was significantly less saline before 1920. These records are described in prior testimony and comments (Exhibits Antioch-217, Antioch-218, Antioch-231, and Antioch-216). Available data and information indicate clearly that the salinity regime of the Delta shifted in the early 1900s as a result of upstream water management practices and changes to the configuration of the Delta, including reclamation and removal of freshwater tidal marshes and levee construction. Prior to about 1917, the water that was present at the Antioch intake would have been predominantly fresh.

5.2. Water quality at Antioch declined markedly after the early 1900s.

Water storage, diversion, and export projects in the Delta continued to increase in size and number through the mid- to late 1900s, exacerbating the saltwater intrusion that began in the early 1900s. The reservoir capacity in the Sacramento and San Joaquin River basins increased significantly from 1915 through the 1980s, which accommodated an increase in irrigated acreage in the Central Valley (up to approximately 9 million acres by 1985) (Exhibit Antioch-216). The largest reservoir of the CVP, Lake Shasta, was completed in 1945, while the largest reservoir of the SWP, Lake Oroville, was completed in 1968 (Exhibit Antioch-216). In total, the Projects increased storage capacity from 1 MAF in 1920 to more than 30 MAF by 1979 (Exhibit Antioch-216). Total annual diversions and exports from the Delta System are estimated to be up 15 MAF per year (Exhibit Antioch-216). This storage, export, and diversion of water has a significant effect on the timing and magnitude of salinity intrusion and serves to alter the distribution of water in the Delta and results in an increase in salinity in the western Delta (Exhibit Antioch-216).

The Projects typically capture and store water in reservoirs upstream of the Delta during the winter and spring and release flows from upstream reservoirs during the summer and fall months. Thus, the Projects have also changed the timing of freshwater inflows to the Delta, generally reducing winter and spring inflows, and generally increasing summer and fall inflows. In addition, water is currently exported by the Projects from the South Delta, which has changed both the flow rates and direction of flow in Delta channels and the distribution of water and salinity within the Delta.

The water quality in the Delta at the City's intake is a complex function of many factors, including the operation of the Projects and water year type. Delta outflow, which is a measure of the inflows to the Delta less the water exported and diverted from the Delta, is a strong determinant of salinity at the City's intake; salinity at the City's intake is higher when Delta outflow is lower. Historically, the average number of usable water days per water year at the City's intake has been greatest during wet years (when Delta inflows are highest) and has decreased as the water year type becomes drier (i.e., above normal, below normal, dry, and critical) (Figure 2). As described in Section 3.5, DWR's Agreement with the City defines water at the City's intake as usable when the chloride concentration is less than 250 mg/L as measured at slack current after HHT. The average number of days water was usable at the City's intake during wet years from 1969 to 2015 was 223 (n=16 years), while during dry and critical years during this period it was 111 days, and 36 days, respectively (Figure 2).

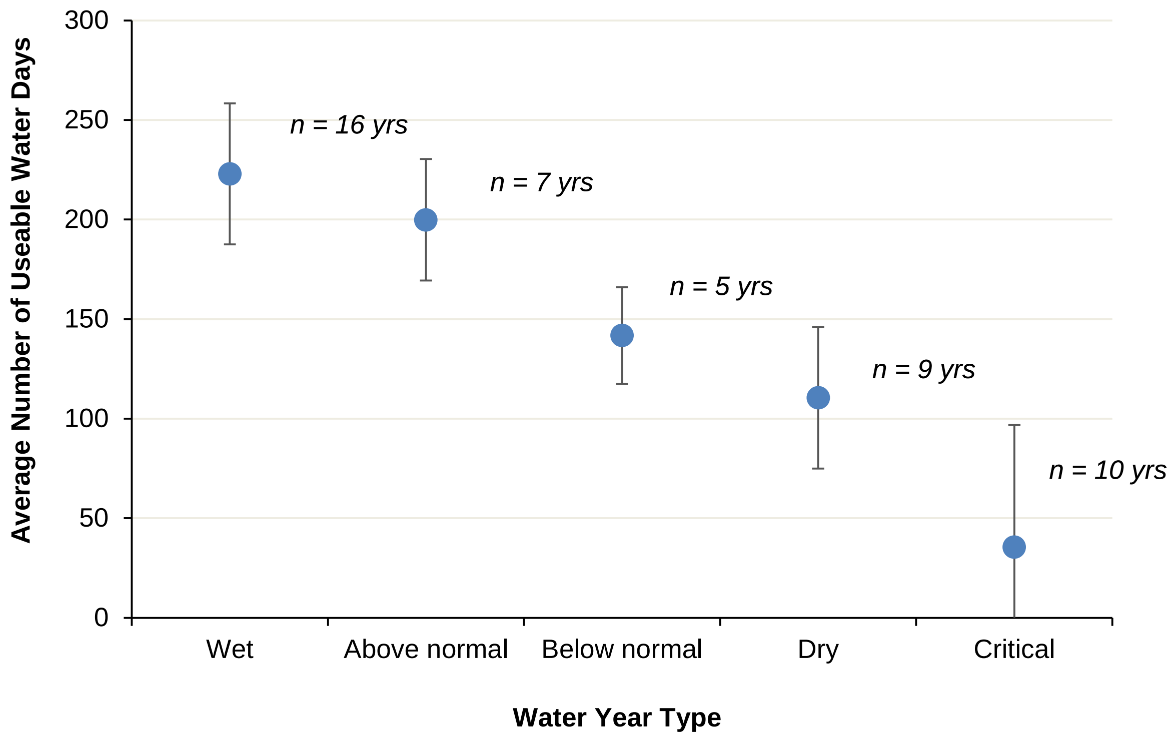

Figure 2 Annual average number of usable water days at Antioch (measured two hours after higher high tide [HHT]) between 1969 and 2015 according to water year type. “n” is the number of years in each water year type category in the 1969–2015 time period. Error bars indicate ±1 standard deviation of the mean.

6. Opinion 2: DWR's evaluation of the proposed WaterFix Project is inadequate.

6.1. DWR's project evaluation uses a flawed and inappropriate baseline.

In its petition for a change in the point of diversion, DWR presents a "no action alternative" (NAA) that it intends to represent "baseline conditions." The NAA scenario represents a future condition and includes about 15 cm of sea level rise but no new facilities. In its petition before the SWRCB, DWR does not present or compare project impacts to existing conditions, even though prior documents and model runs released by DWR utilized two model scenarios, called "EBC1" and "EBC2," that simulate existing conditions (see Antioch-218 and Antioch-219 for additional detail on these model runs).

The appropriate baseline condition for evaluating the impacts of the proposed WaterFix Project is the existing condition. Using a baseline such as the NAA to evaluate harm to Antioch in a change petition process is not appropriate and masks the true impacts of the project on the City. As detailed in Exhibit Antioch-313, Exponent previously evaluated both the EBC1 and EBC2 existing condition model scenarios and found that the EBC2 scenario captured historical salinity at the City's intake location most accurately. To my knowledge, no additional model runs have been conducted by DWR to evaluate hydrodynamics and water quality within the Delta for current conditions; since the existing condition model runs do not involve future environmental changes (e.g., sea level rise) or operations of the WaterFix Project, the EBC2 model scenario is, in my opinion, the best available model run to simulate the existing condition. Furthermore, and as described below, the NAA scenario exhibits higher salinity at the City than EBC2 under some conditions. If the NAA is used as a "baseline" scenario, the effect is to make some of the water quality impacts of the WaterFix Project appear to be less significant than they actually are.

To assess the impact of using the NAA instead of the EBC2 scenario as the baseline in general terms, the chloride concentrations modeled at two hours after higher high tide (as specified in the 1968 Agreement; see Section 3.5) for the two scenarios were compared (see Figure 3) and averaged by water year type. In general, chloride concentrations are simulated to be higher at the City's intake under the NAA scenario than the EBC2 scenario during the winter, late summer, and fall months. These differences are more pronounced during critical, dry, and normal water year types and less pronounced during wet years, when water quality is generally less of an issue. During critical water years, the chloride concentration at the City's intake never drops below the 250 mg/L; i.e., there are no usable water days on average during critical water years.

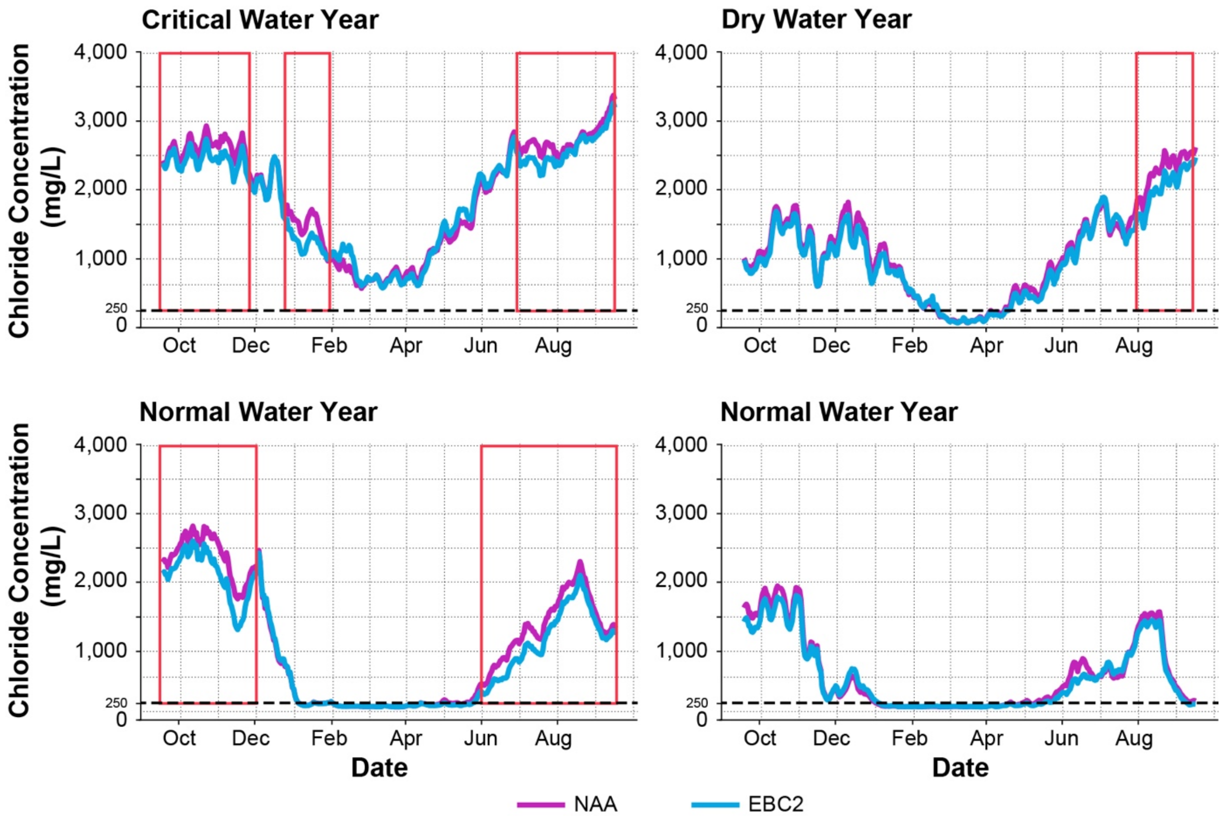

Figure 3 Concentration of chloride at Antioch's intake as modeled by DSM2 (simulated two hours after higher high tide [HHT]) averaged for a given water year type.

6.2. California WaterFix operations are ill-defined.

It is difficult for the City to assess the potential impacts of the WaterFix Project to its water rights and water supply because the Project, as proposed and analyzed in the RDEIR/SDEIS and May 2016 modeling, is not clearly defined, and future operating scenarios are not clearly described. The incomplete and unclear description of the WaterFix Project and operations also makes it problematic to assess or determine impacts to water quality at the City's intake.

DWR's May 2016 modeling effort evaluated five scenarios: the no action (no project) alternative (NAA), plus four model scenarios intended to describe the potential operations of the Project: Boundary 1 (B1), Boundary 2 (B2), H3, and H4. These scenarios describe a broad range of potential operations, and little information is given regarding the criteria by which the Project would be operated, or the criteria for changes in operations over time. For example, DWR states,

> "*Alternative 4A is described by initial operational criteria that provides for a range of outflow. This range is described as initial operational scenarios H3 and H4. However, prior to operation of the project, there will be specific initial operating criteria set forth in the CWF BiOp . These criteria may change based on adaptive management. Since the BiOp has not be issued, and DWR and Reclamation do not know the initial operational criteria the analysis framework presented for Part 1 is a boundary analysis. The boundary analysis will*

provide a broad range of operational criteria and the initial operating criteria will fall within this range. These boundaries are sufficiently broad as to assure the State Water Board that any operations considered within this change petition proceeding have been evaluated with regard to effects on legal users of water."[11]

Initial operational scenarios H3 and H4 fall within the range of outflows produced by the B1 and B2 scenarios and are bounded by those conditions. Scenarios B1 and B2 are intended to represent the "bookends" of operational states that may be implemented under the Adaptive Management and Monitoring Plan (AMMP). As described below, the AMMP is a project management strategy that allows for wide flexibility in determining the rate, volume, and time of water diversion from the Sacramento River.

DWR's testimony notes that operation of the WaterFix Project under Scenario B1 parameters "reflects a condition of less regulatory restriction on operations than the NAA. In this scenario, Delta outflow objectives are set per the D-1641 requirements. The Fall X2 and San Joaquin River inflow-export components from the Biological Opinions are not included in this scenario."[12] Specifically, scenario B1 does not include "additional spring Delta outflow, additional OMR flows, existing I/E ratio, and the existing Fall X2 flow requirement imposed in the existing BiOp for Delta Smelt."[13]

In contrast,

> "*Boundary 2 reflects a condition of significantly increased delta outflow targets and increased restrictions on south delta exports as compared to the NAA… Delta outflow targets are significantly increased throughout the year, but particularly during winter and spring. More restrictive requirements were set for Old and Middle River (OMR) flows throughout the year that limit south Delta pumping substantially during January through June, and also impose further restrictions during July through December. In addition, modeling for Boundary 2 includes a fully-closed Head of Old River Gate during spring months which further reduces the amount of San Joaquin River water entering Old and Middle Rivers.*"[14]

DWR states that "the purpose of [boundary 2] is to demonstrate a scenario that has more restrictive Delta biological regulatory requirements."[15] DWR's testimony also states that the high outflow conditions were evaluated to "consider increases in outflow, without considerations of water supply benefits, and as such, an alternative that included this operational scenario would likely not meet the project objectives or purpose and need statement."[16] Thus, it

[11] Antioch-220, p. 10:4–14

[12] Antioch-221, p. 15:11–14

[13] Antioch-220, p. 13:20–22

[14] Antioch-221, p. 15:15–24

[15] Antioch-220, p. 14:7–9

[16] Antioch-220, p. 11

appears that Scenario B2, which results in significant increases in Delta outflows, is not considered to be a realistic operational scenario.

The Project model runs represent a wide range of operational scenarios: compared to the NAA model results, scenario B1 would result in about 1,200,000 acre-feet per year of *additional* exports; scenarios H3 and H4 would result in about 500,000 acre-feet per year of *additional* exports; and scenario B2 would result in 1,100,000 acre-feet per year *less* exports.[17] As detailed throughout this testimony, water quality impacts to the City are greatest under the B1 scenario.

In addition to the broad range of model scenarios, DWR's testimony regarding project operations appears to be contradictory in places. Specifically, and despite statements to the contrary, one of the WaterFix model scenarios (Scenario B1) appears to be *inconsistent* with existing regulatory requirements.[18] Additionally, the criteria for some operational parameters, such as winter and summer outflow, are worded vaguely in the RDEIR/SDEIS: "Flow constraints established under D-1641 will be followed if not superseded by criteria listed above."[19]

The City is particularly concerned that the limited discussion of operational flexibility in the RDEIR/SDEIS indicates that operations will be modified based on impacts to fish species, including operations parameters for both spring outflow (to be managed for longfin smelt)[20] and Fall X2 (to be managed for delta smelt).[21] Although spring outflow and Fall X2 are critical

[17] Antioch-221, p. 18:17–23

[18] For example, the Pierre testimony (Antioch-220) at pp. 12-13 states that "existing regulatory requirements that will not change include: terms imposed through D-1641… water quality objectives … E/I ratio … Fall X2 flow." However, the Pierre testimony at p. 13-14, in describing the Boundary 1 (B1) model scenario, states that "Boundary 1/Existing Outflow represents an operational scenario with most of the existing regulatory constraints… but does not include additional spring Delta outflow, additional OMR flows, existing I/E [*sic*] ratio, and the existing Fall X2 flow requirement… Fall X2 is an area of active investigation in a multi-agency collaborative group, and its future implementation might be adjusted based on the outcome of those investigations so this scenario excluded it from Boundary 1." It is further unclear why DWR refers to the B1 scenario as the "Boundary 1/Existing Outflow" scenario, since the operating assumptions in the B1 model run differ significantly from the operations and requirements currently in use; since Scenario B1 would export approximately 1.2 maf of water more than the NAA and 0.9 maf more water than the EBC2, it should not be considered an existing outflow scenario.

[19] RDEIR/SDEIS at p. 4.1-10, Table 4.1-2 (Exhibit SWRCB-3). "New and Existing Water Operations Flow Criteria and Relationship to Assumptions in CALSIM Modeling" regarding the operations parameter "winter and summer outflow."

[20] See p. 4.1-9 of the RDEIR/SDEIS (Exhibit SWRCB-3), which) indicates that, for spring outflow, "To ensure maintenance of longfin smelt abundance, initial operations will provide a March-May average outflow bounded by the requirements of Scenario H3, which are consistent with D-1641 standards, and Scenario H4,which would be scaled to Table 3-24 in Chapter 3, Section 3.6.4.2 of the Draft EIR/EIS… Adjustments to the criteria above and these outflow targets may be made using the Adaptive Management Process and the best available scientific information available [*sic*] regarding all factors affecting longfin smelt abundance."

[21] For example, p. 4.1-9 of the RDEIR/SDEIS (Exhibit SWRCB-3) indicates that "September, October, November implement the USFWS (2008) BiOp Fall X2 requirements. However, similar to spring Delta outflow and consistent with the existing RPA adaptive management process, adjustments to these outflow targets may be made using the Adaptive Management and Monitoring Program described below and the best available scientific information regarding all factors affecting delta smelt abundance."

determinants of water quality at the City's intake, neither the RDEIR/SDEIS nor the WaterFix testimony indicate that operations would be constrained to avoid increases in salinity at the City or to avoid impacts to municipal and industrial (M&I) beneficial uses generally.

Finally, Water Code § 85086(c)(2) requires that appropriate Delta flow criteria be established. Because such Delta flow criteria have not been established to date and have not been incorporated into the WaterFix Project modeling, there is additional uncertainty regarding project operations and project impacts.

As a result of the uncertainty in the operation of the WaterFix Project, it is difficult to predict with any certainty the water quality impacts that will occur at the City's intake. As described below, my analysis of project impacts focused on Scenario B1. The figures and tables referenced in this testimony focus on the existing condition scenario (EBC2), the no action alternative (NAA), and WaterFix Scenario B1. As Jennifer Pierre stated in her oral testimony before the SWRCB on July 29, 2016, the Boundary 1 model scenario can be used as a basis for assessment of harm.

6.3. The Adaptive Management and Monitoring Program is undefined.

DWR has stated that the WaterFix project will operate initially to Scenarios H3 or H4 and that these operations will be modified using the AMMP, ultimately (presumably) operating within the broad boundaries defined by Scenarios B1 and B2. The RDEIR/RDEIS states that the AMMP is to be implemented to develop additional science during the course of project construction and operation and to inform and improve conveyance facilities operational limits and criteria.[22] The AMMP is anticipated to result in modifications to operations of the north Delta bypass flows, south Delta export operations, head of the Old River barrier operations, spring Delta outflows, and the Rio Vista minimum flow standard in January through August.[23]

The AMMP is included within the RDEIR/SDEIS as a means to accommodate flexibility in the proposed project that is required due to the "considerable scientific uncertainty… regarding the Delta ecosystem, including the effects of CVP and SWP operations and the related operational criteria." I agree there is substantial uncertainty in the Delta ecosystem and that an adaptive management strategy is necessary; however, an adaptive management strategy should not be used as a means to circumvent project planning.

RDEIR/SDEIS proposed project Alternative 4A relies heavily on the AMMP to dictate changes in operation of water conveyance facilities, habitat restoration, and other factors during project construction and operation. Even though the AMMP is a central component of the WaterFix Project, it remains almost wholly undefined. The RDEIR/SDEIS provides little information beyond an introduction to basic principles of adaptive management; the RDEIR/SDEIS does not describe how the AMMP will be implemented, and it does not appear to include a review

[22] Exhibit SWRCB-3 (RDEIR/SDEIS), p. ES-37:32–37

[23] Exhibit SWRCB-3 (RDEIR/SDEIS), p. ES-18

process for the operational changes that may be recommended as a result of the AMMP.[24] The AMMP is described as a means of making adjustments to operations criteria, but there is no discussion of how this iterative process will occur. In addition, no operational boundaries are defined with regard to potential application of the AMMP that would operate to reduce increased salinity caused by WaterFix and the operations of the State and Federal water management projects. Without information to the contrary, and as indicated by DWR's testimony, I assume that the AMMP would allow operations consistent with the B1 operating scenario; as detailed in these comments, Scenario B1 operations criteria would result in significant increases in salinity at Antioch.

The RDEIR/SDEIS states that "collaborative science and adaptive management will, as appropriate, develop and use new information and insight gained during the course of project construction and operation to inform and improve… the operation of the water conveyance facilities under the Section 7 biological opinion and 2081b permit…" As with the discussion of project operations, the RDEIR/SDEIS appears to indicate that the only factor that will be considered in modifying operations will be impacts to fish. The City is concerned that an AMMP focused solely on fish will fail to consider potential impacts to other beneficial uses, including the potentially substantial water quality impacts that could be induced by even modest changes to project operations.

The RDEIR/SDEIS states, "For the purposes of analysis, it is assumed that the Collaborative Science and Adaptive Management Program (AMMP) developed for Alternative 4A would not by itself, create nor contribute to any new significant environmental effects."[25] Considering the previous discussion and the water quality impacts that would occur at the City as a result of the implementation of B1 parameters (see Sections 7 and 8 below), this statement appears to be unfounded and unreasonable.

6.4. DWR's proposed project operations and modeling are inadequate to demonstrate that water quality standards will be met.

Although DWR states in their testimony that they will be able to operate the project in accordance with D-1641 water quality standards,[26] this assertion appears to be based upon the operational flexibility built into the proposed project and has not been demonstrated through modeling or analysis. Rather, as discussed in Opinion 5 below, it appears that D-1641 water quality criteria will most likely not be met under the proposed project.

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[24] The Delta Independent Science Board also noted the lack of clarity regarding the adaptive management program. Specifically, Exhibit SWRCB-49 states at p. 5, "The lack of a substantive treatment of adaptive management in the Current Draft indicates that it is not considered a high priority or the proposers have been unable to develop a substantive idea of how adaptive management would work for the project" and there were no "examples of how adaptive management would be applied to assessing—and finding ways to reduce—the environmental impacts of project construction and operations."

[25] RDEIR/SDEIS (Exhibit SWRCB-3) at p. 4.1-18

[26] As stated by the DWR in Antioch-223, p. 7:25–27, "Regulatory compliance with the CWF will be at least as good, if not better, as today given that CWF will add infrastructure flexibility to system operations."

Although DWR provided exhibits intended to illustrate compliance with D-1641, these exhibits do not confirm compliance. For example, DWR states that Exhibit DWR-513 is intended to show compliance with D-1641: "Exhibit DWR-513, Figures CL1-CL3 show the simulated chloride concentrations at Contra Costa Canal, Old River near Clifton Court, and Barker Slough/North Bay Aqueduct (Exhibit DWR-513, pp. 4–5). At all these locations there is year round D-1641 chloride concentration objective to be at or below 250 mg/L. Model results show that the monthly average chloride concentrations for all alternatives at these locations stay below this threshold."[27]

As indicated in this testimony, the data presented in DWR-513 (Exhibit Antioch-207), Figures CL1 through CL3, are monthly average chloride concentrations from the 16-year period. (In fact, DWR states that "[s]ince CalSim II is a model with a monthly time-step and a number of daily D-1641 objectives are active during only portions of a month (e.g. April 1 to June 20 and June 20 to August 15), D-1641 objectives are calculated as a monthly weighted average."[28]

However, the D-1641 water quality objectives state that "maximum mean daily" chloride must not exceed threshold values. Salinity in the western Delta can fluctuate significantly on time steps of less than an hour and can vary from day to day. Monthly average chloride concentrations from the 16-year simulation period, as presented by DWR, cannot be used to make conclusions regarding compliance with water quality standards that are evaluated using a daily timestep. To illustrate this point, Figure 4 shows average daily salinity at PP#1 from DWR's model results for WY 1978–1979 for the EBC2, NAA, and B1 scenarios. Figure 4 shows that daily average salinity exhibits significant fluctuations from day to day, and these features are lost when monthly averages are calculated from model (or measured) data. (In addition, and as discussed in more detail in Opinion 5, daily average simulated chloride concentrations at PP#1 exceed the D-1641 water quality objective of 250 mg/L as many as 124 days per year for scenario B1.)

DWR's evaluation of compliance with water quality criteria in recent years is also qualitative and excludes periods during which Temporary Urgency Change Petitions (TUCPs) were issued by the State Board. DWR asserts that "To the extent that recent drought conditions suggest future SWP/CVP operations may require relaxing water quality standards to avoid exceedances, my testimony shows that historical hydrology over the last several drought years are truly unprecedented"[29] and that drought periods like the recent years are "statistical outliers from what would be within the expected range of conditions."[30] Notably absent from DWR's testimony is any discussion or consideration of whether the drought conditions witnessed in recent years are part of a "new normal" instead of "unprecedented" "statistical outliers." Indeed, it seems contradictory that DWR incorporates sea level rise (one outcome of climate change) in their modeling and evaluation of the proposed WaterFix Project at the same time they appear to assume that recent drought conditions will not be repeated in the future.

[27] Antioch-206, p. 6:21–26

[28] Antioch-221, p 5:16–18

[29] Antioch-223, p. 8:3–8

[30] Antioch-223, p. 13:20–22

Drought conditions over the past three years compelled DWR and Reclamation to submit "TUCPs to the State Water Board to modify a subset of the Bay-Delta standard obligations contained in D-1641 in 2014 and 2015. These petitions were approved by the State Water Board with only minor modifications."[31] DWR does not consider exceedance of a WQO a violation "if approval was granted under orders by the State Water Board approving joint TUCPs filed by DWR and Reclamation to modify the SWP/CVPs obligation to meet the requirements."[32] DWR has not indicated whether they anticipate that "compliance" with existing water quality objectives will require TUCP modifications to water quality standards more often in the future than in the past. In any case, DWR's model results do not appear to be predicated on or modified based on the need for TUCPs. In other words, the model results show that simulated water quality is expected to exceed water quality objectives after implementation of the WaterFix project; these exceedances will occur whether or not TUCPs are obtained

[31] Antioch-223, p. 13:13–15

[32] Antioch-223, p. 13:4–7

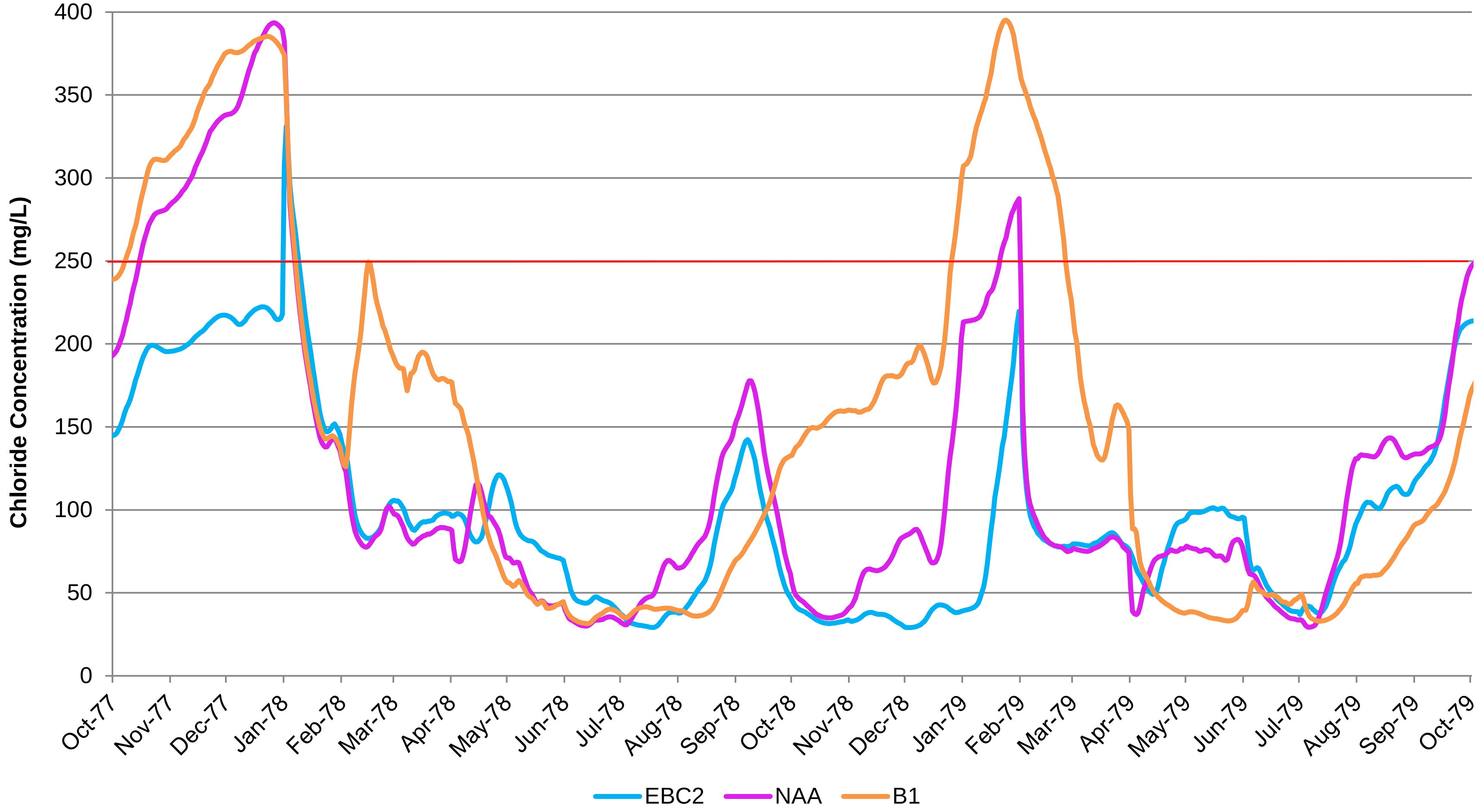

Figure 4 Daily average chloride concentrations at PP#1 for WY 1978–WY 1979, from DWR's model results. The red line indicates the 250 mg/L chloride threshold of D-1641.

7. Opinion 3: WaterFix will result in substantial changes in Delta hydrodynamics and in the composition of water in the Delta.

7.1. WaterFix will almost certainly export more water from the Delta in the future than is currently exported.

DWR's petition asserts that DWR and the Bureau of Reclamation will have greater operational flexibility with the WaterFix Project than currently exists. DWR's testimony states that "Regulatory compliance with the CWF will be at least as good, if not better, as today given that CWF will add infrastructure flexibility to system operations."[33] DWR also states that "the NDD will provide flexibility in ensuring compliance with flow and salinity criteria required by the State Water Board and any other regulatory obligations for CWF…"[34] Although there will be more locations from which water can be exported from the Delta, it is likely that more water, and more high quality Sacramento River water, will be exported from the Delta. Thus, as detailed below, the composition of water within the Delta will change, and water quality within the Delta will be degraded—all factors that will make it more difficult to comply with existing water quality criteria in the future.

Because the WaterFix Project would export more water from the Delta than occurs under existing conditions (exports would increase significantly under scenarios H3, H4, and B1), and because the WaterFix Project would increase both the amount and proportion of high water quality Sacramento River flows removed from the system, implementation of the proposed WaterFix Project is expected to make compliance with water quality criteria even more challenging.

DWR's testimony indicates that operational scenario B1 would result in an average of about 1,200,000 acre-ft per year of additional exports, while scenarios H3 and H4 would result in about 500,000 acre-feet per year of additional exports. Although operational scenario B2 would result in less water exported from the Delta, it appears that this scenario is unlikely to be implemented, as it would not "meet the project objectives or purpose and need statement."[35]

Because Delta channels are below sea level, they will always contain water, but the source of the water will change as water is exported from the system. If more fresh water is removed from the system, Delta outflow will decline, and higher salinity water from San Francisco Bay will flow into the Delta. Similarly, if more water is removed from the NDD and less water is removed from the South Delta, the residence time of water in the South Delta will increase and the composition of water in the Delta will change over time.

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[33] Antioch-223, p. 7:25–27

[34] Antioch-223, p. 16:7–9

[35] Antioch-220, p. 11

Figure 5 shows the amount of water that would be exported from the Delta under the model scenarios EBC2 (existing condition), NAA (no action alternative), and B1 (high export scenario). Exports in the B1 scenario are divided to show the location from which water was exported from the Delta in the model simulations: either from the South Delta or from the NDD. (Of course, both the EBC2 and NAA scenarios would involve exports from the South Delta only.) The results in Figure 5 are averaged by water year type (i.e., export quantities were calculated for each month in the simulation period and averaged by month for each year type [wet, normal, dry, and critical]). In all but critical years, the annual average volume of water exported from the Delta is higher for Scenario B1 than for either existing conditions or the NAA model scenario. During some months of some year types, the amount of water exported from the Delta would increase as much as four-fold. During May of normal water years, for example, modeled exports from Jones and Banks pumping plants are on the order of 2,000 cfs for EBC2 and NAA, but the volume of water is simulated to increase to approximately 8,500 cfs under B1 operations (i.e., exports would increase by more than 400%). During dry years, exports under scenario B1 increase for the months of October, November, and January through May by as much as 3,000 cfs (simulated mean increase in March of dry years). During wet and normal water years, an additional 1,000 cfs (approximately) is exported monthly for the B1 scenario compared to EBC2 and NAA.

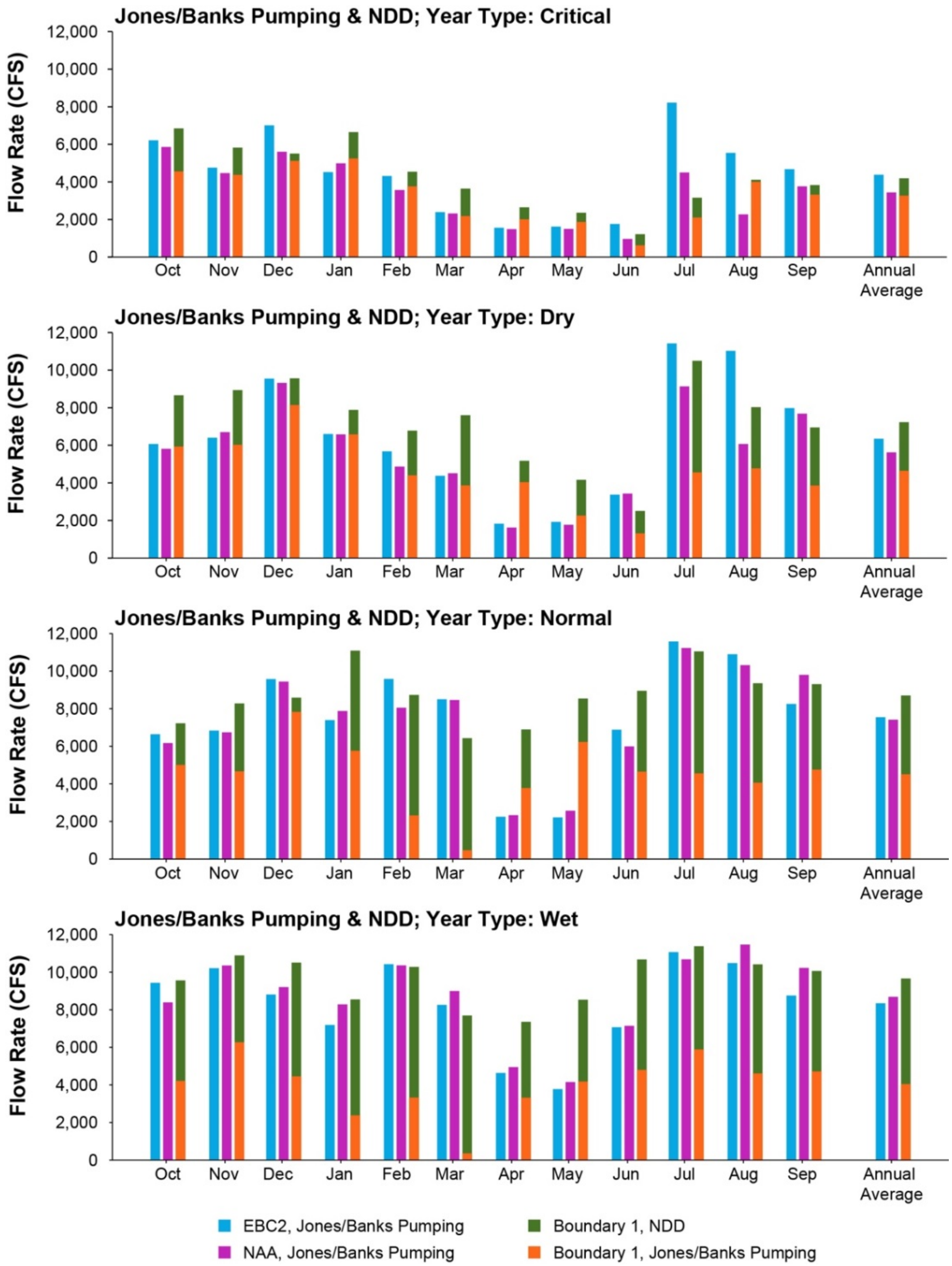

Figure 5 Quantity of water that would be exported from the Delta under the model scenarios EBC2 (existing condition), NAA (no action alternative), and B1 (high export scenario) as modeled by DWR's DSM2 data. Exports in the B1 scenario are divided to show the location from which water was exported from the Delta in the model simulations: either from the South Delta or from the NDD. Results are averaged by water year type (i.e., export quantities were calculated for each month in the simulation period and averaged by month for each year type, wet, normal, dry, and critical).

7.2. Not only will WaterFix remove more water from the Delta, it will remove a higher fraction of Sacramento River water than current project operations, resulting in changes in the composition and quality of water within the Delta.

Because the new NDD intakes are located on the Sacramento River in the northern part of the Delta, water exported from these locations will consist almost entirely of Sacramento River water, reducing the amount of Sacramento River water available in the Delta for use by other water users. In this scenario, the composition of water available for export for downstream users would change, generally including higher proportions of water from other sources, including the San Joaquin River and agricultural return flows. To evaluate the source of the water at the City's intake under the various model scenarios, we used DWR's model input files to conduct fingerprinting runs using the DSM2 model, as described in Section 3.1.

The source of water in the Delta largely determines the water quality, including the salinity, of water within the Delta. In general, the salinity of the Sacramento River is low, about 100 mg/L TDS; the salinity of water in the eastside streams is also low, typically less than 100 mg/L TDS.[36] In contrast, the salinity of the San Joaquin River is generally higher; in 2015, the salinity of San Joaquin River water varied from 48 to 776 mg/L TDS (average 343 mg/L TDS).[37] In addition to salinity, San Joaquin River water is typically higher in bromide and other chemicals than other freshwater sources to the Delta (Exhibits Antioch-224 and Antioch-225). Agricultural return flows are also a source of salinity to the Delta as a result of the concentration of salts from soils, from fertilizers used within the Delta, and from evaporation of water applied for irrigation (Exhibit SWRCB-27). Although there are many sources of agricultural return flows, few have been characterized with respect to salinity levels or flow rates; however, agricultural return flows will have higher salinity levels than the water diverted for irrigation as a result of the factors mentioned above. It has been estimated that, in the San Joaquin River at Vernalis, agricultural surface runoff occurring upstream of Vernalis accounts for up to 43% of total salt loading in the San Joaquin River at Vernalis[38] (Exhibit Antioch-224, based on historical data 1977–1997). Bay water, as recorded at Martinez (the western boundary of the DSM2 model) varies from nearly fresh in times of high Delta outflow to 32,000 mg/L TDS during the fall months of dry years.[39] See Exhibit Antioch-217 for more detail.

My analysis shows that the chloride concentration at the City's intake is correlated to the percentage of water from Martinez at the intake: the chloride concentrations are high when the percentage of Martinez water is high (by volume). (I have previously examined the ability of the DSM2 model to simulate salinity within the Delta. Although DSM2's ability to simulate salinity and chloride concentrations within the interior Delta, particularly the south Delta, is limited, DSM2 is able to simulate salinity at Antioch well, in large part because much of the salinity at

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[36] Data obtained and reviewed from CDEC, accessed online at http://cdec.water.ca.gov/

[37] Data obtained from CDEC, accessed online at http://cdec.water.ca.gov/

[38] Salt loading to rivers and tributaries far upstream of the Delta from agricultural practices in the Central Valley may exacerbate and increase the salt loads into the Delta.

[39] By contrast, the salinity of seawater is approximately 35,000 mg/L TDS.

Antioch's intake derives from Bay water. See Exhibit Antioch-217 for additional detail.) Chloride concentrations are also generally inversely correlated with the percentage of Sacramento River present at the City's intake: a higher percentage of Sacramento River water correlates to a lower salinity.

The fingerprinting analysis shows that for nearly all water year types and months the fraction of Sacramento River water at the City's intake will be lower for operational scenario B1 than for scenarios EBC2 and NAA. Under operational scenario B1, an additional 1,200,000 acre-feet per year of exports will occur, on average; as shown in Figure 6, the fraction of Sacramento River water at the City's intake will decline in all year types. In some years, this "lost water" will be made up primarily by San Joaquin River water. For example, in March of a normal water year, the fraction of Sacramento River water decreases from 60% to 40% when scenario B1 is implemented (relative to EBC2 and NAA baselines), while the fraction of San Joaquin River water increases from 20% to 40% (Figure 7). The increase in the fraction of San Joaquin River water results in degraded water quality at the City's intake.

Simulation results show that during all water year types the fraction of water from Martinez (the Bay) at Antioch's intake will increase significantly through summer and fall and into winter. The specific timing varies by water year type; e.g., during critical and dry years the percentage begins to increase in April and remains high (20% to 30%) through January, and during normal and wet water years salinity begins to increase during June and decreases during December (Figure 8). Because water from Martinez is frequently much more saline that water from other sources, even a small increase in the fraction of water from Martinez can cause significant increases in the salinity of water at the City's intake. In October of dry years, for example, the fraction of Sacramento River water is simulated to decrease from approximately 85% to 62% when scenario B1 is implemented, while the fraction of Martinez inflow is simulated to increase from approximately 10% to 30%.

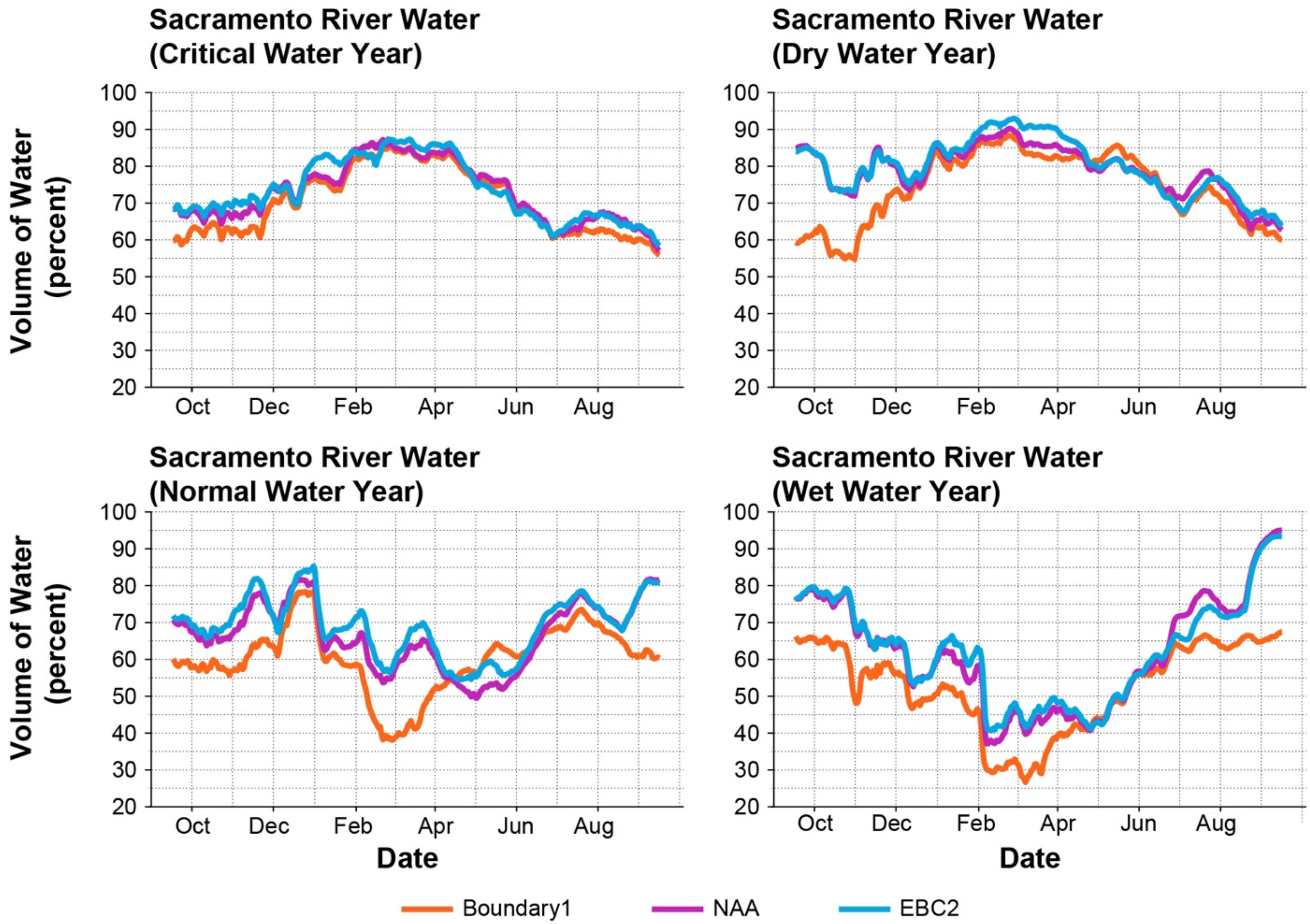

Figure 6 Source fractions of Sacramento River water at Antioch's intake as modeled by DSM2, averaged by water year type.

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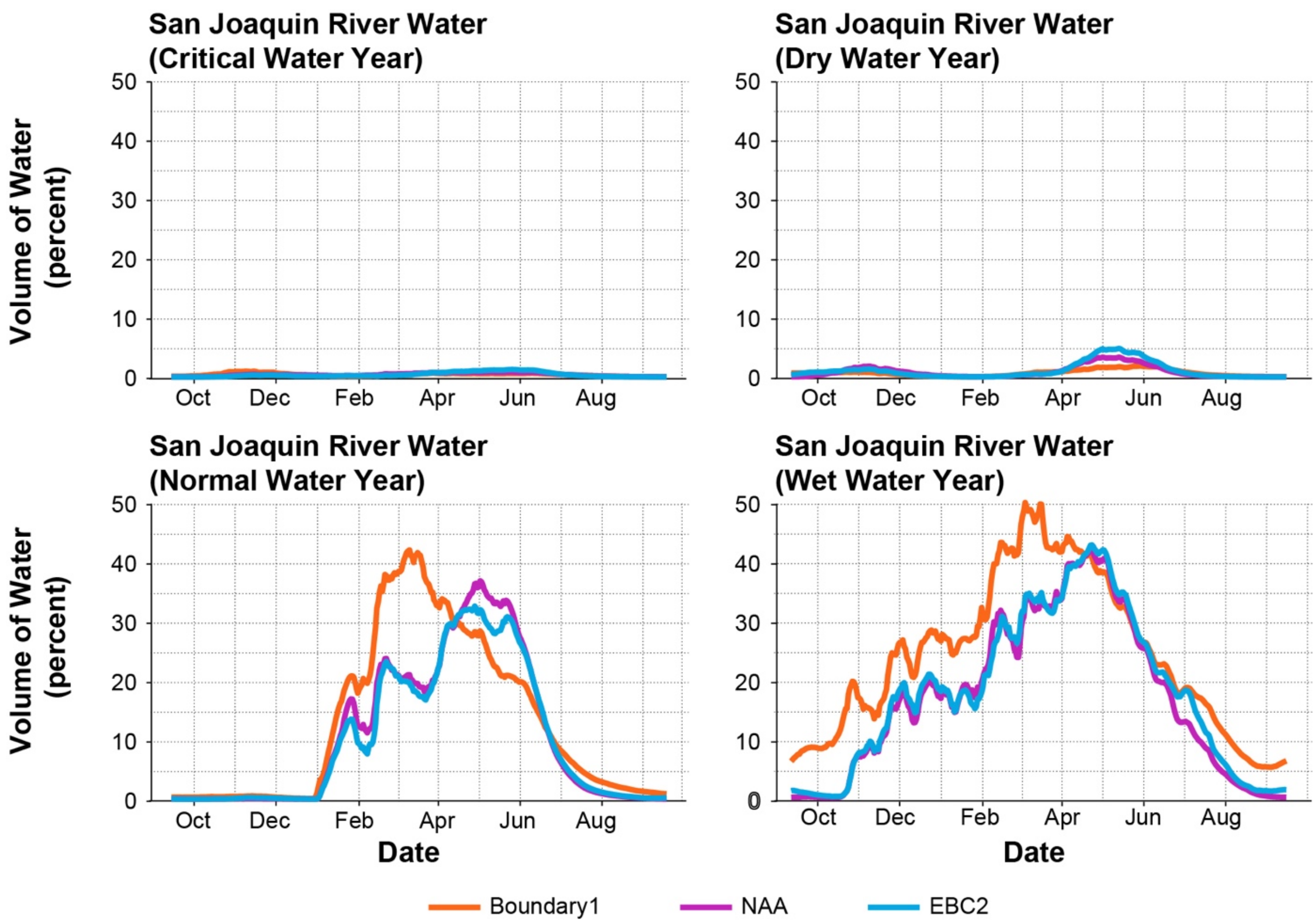

Figure 7 Source fractions of San Joaquin River water at Antioch's intake as modeled by DSM2, averaged by water year type.

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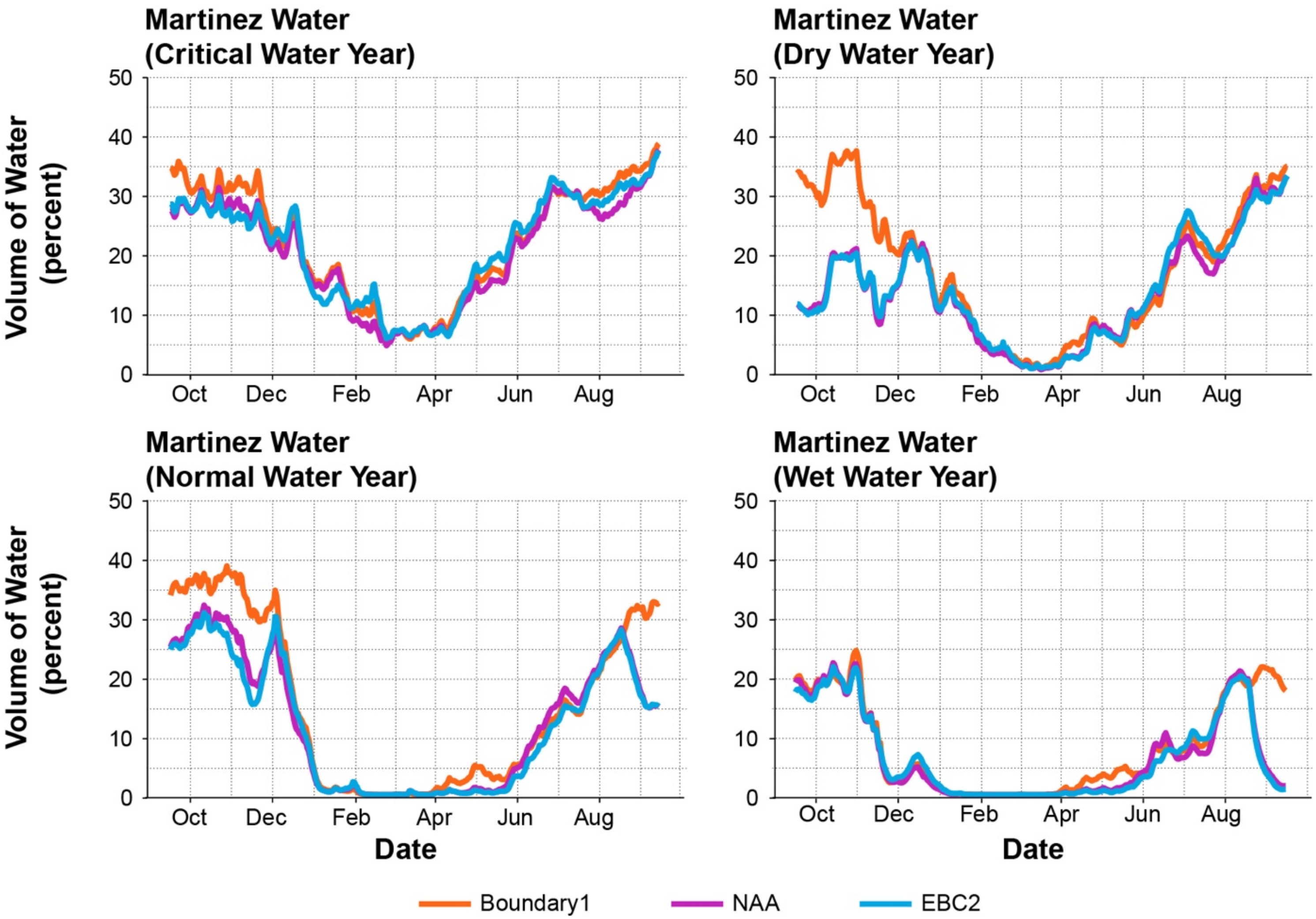

Figure 8 Source fractions of water from Martinez at Antioch's intake as modeled by DSM2, averaged by water year type.

8. Opinion 4: WaterFix will result in increased salinity at Antioch's intake and will increase the number of days that Antioch must purchase water from other sources.

8.1. Salinity at Antioch's intake is expected to increase for most scenarios modeled under WaterFix.

Electrical conductivity (EC) was simulated at the City's intake by DWR from 1976 to 1991. I converted DWR's simulated EC levels to chloride concentrations using the salinity conversion methods described in 3.2 for the proposed scenarios NAA, EBC2, and B1, in order to evaluate water quality impacts to the City's water supply under the WaterFix Project. The model results were used to extract chloride concentrations at the City's intake two hours after HHT (i.e., at slack current following HHT, as described in the 2013 Amendment to the City's 1968 Agreement; see Section 3.5) and to calculate the number of days that the chloride concentration at slack current following HHT is predicted to exceed 250 mg/L (i.e., the salinity threshold in the 1968 Agreement). Model results were also used to calculate the monthly average chloride concentration for each model scenario and for each year type classification.

The general increase in simulated chloride levels is shown in Table 2, which presents the change in monthly average values of the daily chloride concentration at slack current following HHT at the City's intake for the B1 scenario relative to existing conditions (the EBC2 scenario). As shown in Table 2, positive values indicate an increase in chloride concentrations (averaging concentrations for each day at slack current after HHT). Of the 48 entries, all but two are positive, indicating an increase in chloride concentrations. In 29 of the 48 entries in Table 2, the increase in the chloride concentration (averaging concentrations for each day at slack current after HHT) is between 100 and 1000 mg/L, and in five of the entries, the increase in the chloride concentration (averaged as described above) is greater than 1000 mg/L. The increase in chloride concentrations (for scenario B1 relative to existing conditions EBC2) is greatest during the summer and fall months.

DWR's model results were also used to compute the number of days per year that water at the City's intake is usable, consistent with the 1968 Agreement as detailed in Section 3.5. As shown in Table 3, the number of days in which water is not usable is greater under the B1 scenario than under current conditions (EBC2) for all water years with the exception of water year 1977, which had no usable days under any scenario. Table 4 aggregates the results in Table 3 by year type and shows that the usability of water at the City's intake decreases in all year types for scenario B1 relative to existing conditions. The loss in terms of days of usable water is shown in Table 5 and is greatest in wet and normal year types. These results indicate that the implementation of the B1 scenario will impact water quality at the City's intake more during normal and wet years than during dry and critical years. Figure 9 further illustrates these impacts, showing simulated daily chloride concentrations at slack current after HHT as averaged over "normal" years (1978–1980); as shown in this figure, chloride concentrations are predicted to increase for Scenario B1 relative to existing conditions in all months except portions of January, February, and March, and water that would have been usable under existing conditions exceeds the usability threshold of 250 mg/L for Scenario B1 during portions of April, May, and June.

Table 2 Difference in monthly average chloride concentration (mg/L) at Antioch's intake at slack current after HHT for Scenario B1 relative to existing conditions (EBC2). Positive numbers indicate an increase in chloride concentrations for Scenario B1 relative to existing conditions (EBC2).

	Difference in Chloride Concentration (mg/L) between B1 and EBC2 at Antioch			
	Wet WY	**Normal WY**	**Dry WY**	**Critical WY**
Jan	-2	149	408	380
Feb	4	9	97	132
Mar	1	9	46	37
Apr	27	52	114	113
May	187	214	123	34
Jun	205	257	8	-15
Jul	153	347	121	249
Aug	272	359	453	381
Sep	1395	1304	548	339
Oct	333	969	1895	608
Nov	223	1381	1596	638
Dec	12	901	819	410

Table 3 Number of days per year when water is not usable at the City's intake (i.e., when that the chloride concentration at Antioch's intake is greater than 250 mg/L at slack current after HHT), calculated from DWR simulation results.

		Number of Days Chloride > 250 mg/L		
Water Year	Water Year Type	EBC2[b]	NAA[a]	B1[a]
1976	critical	332	340	361
1977	critical	365	365	365
1978	normal	204	200	206
1979	normal	220	220	261
1980	normal	206	192	226
1981	dry	280	268	291
1982	wet	140	118	162
1983	wet	45	0	65
1984	wet	131	114	180
1985	dry	270	280	326
1986	wet	209	202	239
1987	dry	286	297	311
1988	critical	306	325	331
1989	dry	291	288	299
1990	critical	356	341	357
1991	critical	325	326	326

[a] WaterFix model runs (05/2016)
[b] EIR/EIS model run EBC2 (2013), the existing condition model run most representative of current conditions

Table 4 Average number of days per year in each year type when water is not usable at the City's intake (i.e., when that the chloride concentration at Antioch's intake is greater than 250 mg/L at slack current after HHT), calculated from DWR simulation results.

	Average Number of Days Chloride > 250 mg/L		
Water Year Type	EBC2[b]	NAA[a]	B1[a]
Wet	131	109	162
Normal	210	204	231
Dry	282	283	307
Critical	337	339	348

[a] WaterFix model runs (05/2016)
[b] EIR/EIS model run EBC2 (2013), the existing condition model run most representative of current conditions

Table 5 Decrease in number of days of water usability at Antioch's intake, averaged by water year type, compared to existing conditions.

Water Year Type	Number of Lost Usable Water Days Relative to EBC2	
	NAA[a]	B1[a]
Wet	22	53
Normal	6	27
Dry	-1	24
Critical	-2	-9

[a] WaterFix model runs (05/2016)

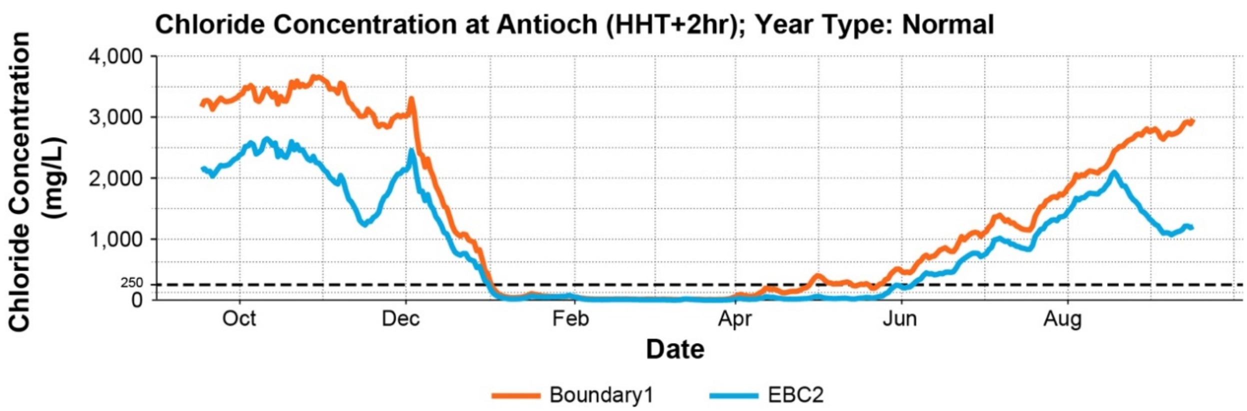

Figure 9 Daily chloride concentrations in water at Antioch's intake location as modeled by DSM2 (at slack current after HHT) and averaged for each day for normal water years.

8.2. Increased salinity will impact the City's operations.

The modeled salinity at the City's intake shows the clear potential for significant impacts on the City's diversion and treatment operations. Implementation of the WaterFix Project, particularly under Scenario B1, is simulated to lead to significant water quality degradation. As shown in Section 8.1, water would be "usable" at the City's intake for fewer days under the B1 scenario relative to existing conditions (EBC2) and relative to the NAA scenario. Currently, the City diverts water at its intake to the City's treatment facility if the chloride concentration is less than 250 mg/L.

The 1968 Agreement defines the number of usable water days each year; however, the City operates their intake facilities and water treatment operations according to real-time salinity measurements in the San Joaquin River. The amount of time per year the City can use their intake, defined as "equivalent" days, was calculated from model results for operational scenarios NAA, EBC2, and B1 (see methods Section 3.6). As discussed in Section 6.1, the

EBC2 scenario represents existing conditions most accurately and was thus used to compare water quality impacts under other operational scenarios. Table 6 provides the number of equivalent days, calculated from DWR's model results, that chloride levels in water at the City's intake are predicted to be below the specific chloride benchmark value of 250 mg/L.

Table 6 shows that during all water year types, operational scenario B1 is predicted to result in significant degradation of water quality relative to the EBC2 scenario, resulting in fewer equivalent days per year. The analysis shows that, overall, the 250 mg/L threshold value will be exceeded more frequently at the City's intake under scenario B1 than the under the existing EBC2 baseline condition. Under operational scenario B1, there would be *fewer* days per year that the City can use their intake on average during all year types than under either the EBC2 existing condition or the NAA.

Table 6 Average number of equivalent days per year Antioch's water treatment plant can use water at the intake (i.e., total amount of time, expressed in days, when water at the City's intake is simulated to have a chloride concentration of less than 250 mg/L) assuming real-time operations.

	Average Number of Equivalent Water Days per Year		
Water Year Type	**EBC2[b]**	**NAA[a]**	**B1[a]**
Critical	63	66	44
Dry	145	134	102
Normal	188	171	163
Wet	270	265	240

[a] WaterFix model runs (05/2016)
[b] EIR/EIS model runs (2013), existing condition model run most representative of current conditions

8.3. The proposed project will have economic impacts on Antioch's water purchase and treatment operations.

When the water at the City's intake is too saline, the City must purchase water from CCWD. Water is purchased from CCWD either to replace water that cannot be diverted from the City's intake or to provide fresh water for blending with water that is diverted from the City's intake but is too saline to use alone. The City blends water from its intake with purchased water in order to minimize customer impacts and complaints that occur due to saltier tasting water.

To evaluate the impact of anticipated additional purchases of water to the City, I calculated the present value of water that will need to be purchased as a result of the WaterFix Project, given WaterFix operations scenario B1 and using the calculation method details in Section 3.7. The cost of water purchases was calculated for the 50-year period of time (2028–2078) that the

WaterFix project is expected to be operational. Calculation results show that the present value (2016 dollars) of costs expected to be incurred by the City for each operational scenario is approximately $342 million, $355 million, and $389 million for the existing condition (EBC2), NAA, and Boundary 1 scenarios, respectively, over the 50-year project period. On a water year type weighted annual average basis, the annual average cost of water per year in 2028 is expected to be on the order of $9.0, $9.4, and $10.3 million per year for EBC2, NAA, and Boundary 1, respectively. These values are indicative of the water quality degradation that Antioch currently experiences and the additional degradation expected from WaterFix operations. In 2028 dollars, Antioch expects to pay an additional $66 million over the 50 years following construction of the WaterFix project (Scenario B1) in addition to the $436 million they expect to pay under the existing condition scenario (EBC2). These calculations and costs are presented in Table 7.

The largest annual increase in water purchase costs that would be expected based on the model results for the simulation period was found to occur during the dry year of 1985. The present value of water that would be purchased if a year like 1985 occurred after implementation of WaterFix is $6.9 million for EBC2, $7.5 million for NAA, and $8.9 million for the B1 scenario.

Table 7 Anticipated cost of water purchases by 2028 based on Antioch diversion and treatment operations under WaterFix Project scenarios EBC2, NAA, B1.

	Modeled Annual Cost of Water Purchases by 2028 (million dollars in 2028)		
Water Year Type (% recurrence)	**EBC2[b]**	**NAA[a]**	**B1[a]**
Critical (16%)	$14.4	$14.3	$15.0
Dry (22%)	$11.2	$11.6	$12.9
Normal (33%)	$8.6	$9.3	$9.9
Wet (29%)	$4.7	$5.4	$6.3
Annual weighted average by WYT (2028 $, millions)	$9.0	$9.4	$10.3
Total purchases over 50-years (2028 $, millions)[c]	$435.6	$458.6	$501.4
Present value of total purchases over 50-years (2016 $, millions)	$305.5	$321.7	$351.7

[a] WaterFix model runs (05/2016)
[b] EIR/EIS model run EBC2 (2013), the existing condition model run most representative of current conditions
[c] Assumes a 3% annual interest rate, 3% discount rate (see Section 3.7 for detail)

8.4. In Addition to Increased Salinity, Other Water Quality Impacts Will Occur at the City's Intake

In addition to increases in chloride concentrations (i.e., salinity), the City is concerned about increases in bromide concentrations that will be caused by the proposed project. As discussed in Section 3.2, the concentration of bromide in Delta waters has been found to correlate positively and linearly with the concentration of chloride, such that the ratio of bromide to chloride is relatively constant throughout the Delta (Exhibits Antioch-206; Antioch-224; Antioch-225). Thus, an increase in chloride levels at the City's intake indicates that similar increases in bromide levels will occur. Bromide, like chloride, may form carcinogenic disinfection byproducts (e.g., brominated organic compounds, trihalomethanes [THMs] and haloacetic acids [HAAs]) during chlorination and chloramination in the water treatment process.[40] The Antioch water treatment plant uses chloramination for water disinfection. Brominated disinfection byproducts have been linked to cancer and genotoxicity and pose a human health risk through various routes of exposure, including ingestion (e.g., consumption of drinking water), inhalation, and dermal exposure (e.g., during showering or bathing). Brominated disinfection byproducts are suspected to pose a greater health risk than chlorinated disinfection byproducts, and their presence in drinking water intake supplies is a significant concern (Exhibits Antioch-226, Antioch-227, and Antioch-228).

The RDEIR/SDEIS notes that under the scenarios evaluated in the RDEIR/SDEIS (which did not include scenarios B1 or B2), "multiple interior and western Delta assessment locations would have an increased frequency of exceedance of 50 µg/L, which is the CALFED Drinking Water Program goal for bromide as a long-term average applied to drinking water intakes… These locations [include] San Joaquin River at Antioch… Similarly, these locations would have an increased frequency of exceedance of 100 µg/L, which is the concentration believed to be sufficient to meet currently established drinking water criteria for disinfection byproducts… The greatest increase in frequency of exceedance of 100 µg/L would occur at Franks Tract (6% increase) and San Joaquin River at Antioch (4-5% increase depending on operations scenario)."[41] Appendix B to the RDEIR/SDEIS presents the results of sensitivity studies showing estimated bromide concentrations at the City for "periods of historically acceptable water quality for withdrawal." The sensitivity studies show that bromide concentrations would increase significantly at the City; for example, in February through April of wet and above normal year types, RDEIR/SDEIS model analyses (which do not include scenarios B1 or B2) indicate that bromide concentrations are expected to increase from below the 100-µg/L threshold for both the existing conditions (EBC2) and the No Action Alternative-ELT scenarios to levels well above the 100-µg/L threshold for Alternative 4A Operations Scenarios H3 and

[40] Other disinfection processes, such as ozonation and ultra-violet (UV) disinfection, are also reported to produce disinfection byproducts (Exhibit Antioch-227)

[41] RDEIR/SDEIS at p. 4.3.4-9 (Exhibit SWRCB-3). Regarding the City's intake, the RDEIR/SDEIS discussion regarding bromide states (incorrectly) that "the use of seasonal intakes at these locations is largely driven by acceptable water quality, and thus has historically been opportunistic. Opportunity to use these intakes would remain, and the predicted increases in bromide concentrations at Antioch and Mallard Slough would not be expected to adversely affect MUN beneficial uses, or any other beneficial use, at these locations."

H4, respectively.[42] Yet the RDEIR/SDEIS concludes that impacts due to bromide are "less than significant."[43] The conclusion of the RDEIR/SDEIS is not credible.

As noted in Section 8.1, chloride levels at the City's intake are simulated to increase under Scenario B1 relative to existing conditions (EBC2) and relative to the NAA. A chloride concentration of 250 mg/L is equivalent to a bromide concentration of 880 µg/L, well above the thresholds of significance identified in the RDEIR/SDEIS. Furthermore, Scenario B1 anticipates the export of significantly more water than Scenarios H3 and H4, two of the scenarios evaluated in the RDEIR/SDEIS, and chloride levels under Scenario B1 would increase at the City's intake location to a greater extent than under the scenarios evaluated in the RDEIR/SDEIS. Because an increase in chloride concentrations correlates directly to an increase in bromide concentrations, it is my opinion that the RDEIR/SDEIS has not captured the full range of potential impacts due to bromide.

DWR's testimony states that "There are three municipal diversion locations where bromides may be of concern. Two of which DWR has contracts that address SWP operations. (Exhibits DWR-303, DWR-310, DWR-304.)"[44] One of the municipal diversion locations referenced by DWR is the City of Antioch (Exhibit DWR-310). Although certain advanced water treatment processes (e.g., those used for desalination) can remove or enhance the removal of bromide from drinking water supplies prior to disinfection, these processes are not part of Antioch's water treatment facility and would have significant capital and operational costs if they were added. Treatment processes that can remove bromide include membrane filtration, electrochemical removal, and adsorption (e.g., onto activated carbon) (Exhibit Antioch-227). The City has been working with engineers to estimate the cost of such a treatment facility, and the preliminary information available to the City indicates that a water treatment plant with 6-8 mgd capacity would have a capital cost on the order of $150 million.

Additionally, a change in the source of water at the City's intake may result in increased concentrations of pesticides, herbicides, and nitrogen and phosphorus-containing compounds associated with the agricultural return flows that impact the Delta and the San Joaquin River. A change to a higher proportion of San Joaquin River water, which is simulated to occur under several WaterFix operational scenarios, would likely increase concentrations of salts, nutrients, and pesticides in water at the City's intake.

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[42] See RDEIR/SDEIS Appendix B at p. B-87 (Exhibit SWRCB-3). Note that two methods were used to evaluate bromide concentrations (the "mass-balance modeling approach" and the "EC to chloride and chloride to bromide" modeling approach), and results from the two methods differ. However, 18 of 24 entries in Tables Br-5 and Br-6 at RDEIR/SDEIS Appendix B at p. B-87 show predicted bromide concentrations for Alternative 4, Scenarios H3 and H4 (ELT) greater than 100 µg/L, with the highest value of 178 µg/L; only 6 of 24 entries for either the Existing Conditions or No Action Alternatives show concentrations greater than 100 µg/L. Despite differences in results obtained using the two methods, it is clear that bromide concentrations are expected to increase significantly and to exceed applicable thresholds a much greater percentage of the time.

[43] RDEIR/SDEIS, p. ES-43 (Exhibit SWRCB-3).

[44] Antioch-206, p. 7:17-19

9. Opinion 5: Compliance with water quality standards is likely to be more challenging in the future, and water quality degradation will occur.

9.1. WaterFix Project operations will result in additional exceedances of D-1641 objectives for municipal and industrial beneficial uses.

DWR used modeling to evaluate compliance with salinity and flow objectives specified in D-1641 for the NAA and proposed project scenarios (H3, H4, B1, and B2); modeling was not used to evaluate compliance for existing conditions. I evaluated the proposed operational scenario B1, the existing condition (EBC2), and the future no action alternative (NAA) to assess the frequency of compliance with the water quality objectives specified in D-1641 for municipal and industrial beneficial uses. Specifically, I used DSM2 model results provided by DWR to evaluate compliance with the D-1641 water quality objectives for the 16-year simulation period, as described in Section 3.3. The 16-year simulation period included all water year types, from one of the wettest years on record (1983) to one of the driest (1977). I evaluated the number of simulated exceedances of the 250 mg/L chloride water quality objective of D-1641 at PP#1. The D-1641 150 mg/L chloride water quality objective was evaluated at the City. (Although D-1641 specifies that the 150 mg/L chloride objective can be evaluated at either PP#1 or the City, DWR assesses compliance with this objective only at PP#1, as PP#1 is located east of the City in the Delta and is thus less likely to be impacted by seawater intrusion. Nonetheless, the frequency with which this threshold is predicted to be met at the City is illustrative of the water quality impacts at the City's intake.)

9.2. Compliance with D-1641 250 mg/L Chloride Water Quality Objective will occur less frequently under scenario B1.

DWR's model results show that compliance with the D-1641 250 mg/L chloride water quality objective at PP#1, as calculated by "maximum mean daily" chloride, is challenging under both the existing conditions (EBC2) and the future no project (NAA) scenarios. Model results show that compliance will occur even less frequently under Scenario B1. Thus, DWR's own model results do not appear to support DWR's testimony that increased operations flexibility will result in greater compliance with water quality objectives in the future.

The number of days the threshold of 250 mg/L chloride is not met at PP#1 for each year in the 16-year modeled record is shown in Table 8. Significant variability exists from year to year between the different scenarios; however, Scenario B1 exceeds the threshold value more frequently than other project scenarios than both the existing condition and the NAA. In the dry year of 1989, for example, Scenario B1 exceeds the threshold for 124 days that year, and during the critical water year of 1991 the threshold is exceeded 117 days by Scenario B1. In contrast, the existing condition is simulated to exceed this threshold only 77 and 76 days in 1989 and 1991, respectively.

The data from Table 8 are aggregated in Table 9 by water year type. While the year to year variability is muted some by the aggregation, several general trends are clear. During dry and "normal" (i.e., above normal and below normal) water years and for Scenario B1, the 250 mg/L chloride threshold is exceeded at PP#1 46 and 71 days per year, respectively (Table 9). For critical water years, NAA exceeds the 250 mg/L chloride threshold most often with an average of 44 days; the existing conditions (EBC2) scenario exceeds the threshold most often during wet years.

Table 8 Number of days in each water year that the D-1641 WQO of 250 mg/L chloride for Municipal and Industrial Beneficial Uses at PP#1 is not met, based on DWR model results.

			Number of Days 250 mg/L Chloride Threshold is Not Met at PP#1		
Water Year	Water Year Type	Total Days	EBC2[b]	NAA[a]	B1[a]
1976	Critical	366	37	0	0
1977	Critical	365	8	50	16
1978	Normal	365	10	87	105
1979	Normal	365	0	17	64
1980	Normal	366	87	57	44
1981	Dry	365	0	0	0
1982	Wet	365	3	12	10
1983	Wet	365	34	0	0
1984	Wet	366	0	0	0
1985	Dry	365	0	0	15
1986	Wet	365	23	26	6
1987	Dry	365	0	0	46
1988	Critical	366	1	4	14
1989	Dry	365	77	106	124
1990	Critical	365	40	60	25
1991	Critical	365	76	107	117

[a] WaterFix model runs (05/2016)
[b] EIR/EIS model run EBC2 (2013), the existing condition model run most representative of current conditions

Table 9 Average days per year by water year type that the D-1641 250 mg/L chloride WQO for Municipal and Industrial Beneficial Uses at PP#1 is not met, based on DWR model results.

	Average Number of Days 250 mg/L Chloride Threshold is Not Met at PP#1		
Water Year Type	**EBC2[b]**	**NAA[a]**	**B1[a]**
Critical	32	44	34
Dry	19	27	46
Normal	32	54	71
Wet	15	10	4
Average	25	33	37

[a] WaterFix model runs (05/2016)
[b] EIR/EIS model run EBC2 (2013), the existing condition model run most representative of current conditions

9.3. The D-1641 150 mg/L Water Quality Objective will not be met at Antioch.

D-1641 includes water quality objectives for M&I beneficial uses of 150 mg/L to be met at either PP#1 or at the City's intake, which is located in the San Joaquin River channel. D-1641 specifies that the "maximum mean daily" chloride concentration of 150 mg/L must be met for a specific number of days during the calendar year to be provided in "intervals of not less than two weeks duration" (see Section 3.3). I used DSM2 model output to calculate the number of days per calendar year that the maximum daily chloride concentration at Antioch Water Works Intake is simulated to be below 150 mg/L, considering the requirement that the number of days be met in intervals of not less than two weeks duration. Although DWR does not assess compliance at the City's intake location, where water quality is more likely to be influenced by salty water from the Bay, it is instructive to evaluate salinity at this location, as it is indicative of saltwater intrusion to the Delta.

As shown in Table 10, simulated chloride concentrations at the City's intake routinely exceed the 150 mg/L threshold for M&I beneficial uses. During wet years, water quality objectives, expressed as a certain number of days (dependent on the year type), are met occasionally at the City for the existing condition (EBC2). The B1 and NAA scenarios are predicted to meet water quality objectives only during the single wettest year in the 16-year period. For critical, dry, and above- and below-normal years (normal years), water quality at the City's intake does not meet the 150 mg/L threshold as specified in D-1641 for scenarios Boundary 1, NAA, or EBC2.

Even at the PP#1, DWR's modeling shows that complying with the D-1641 M&I objectives is challenging (see Table 11); compliance is expected to decline in the future under both the NAA and B1 scenarios relative to existing conditions. Table 11 presents the results of the 150 mg/L threshold analysis for the PP#1 location. WQOs are not met during two of the five critical water years in the 16-year model period for the Boundary 1 and NAA scenarios, and WQOs are not met for one of the five critical water years under EBC2 scenario.

Table 12 presents the number of days in each year that chloride concentrations at PP#1 are predicted to be below the threshold of 150 mg/L chloride (and that occur in no less than two-week periods). For some years that are anticipated to comply with the 150 mg/L chloride WQO, the total number of days below the threshold, as counted in two-week consecutive intervals (as specified in D-1641), decreases significantly in certain years. During WY 1979, for example, Scenario B1 has 160 fewer days with a chloride concentration below 150 mg/L than the existing condition (EBC2), yet the benchmark of 175 days met for that year by both scenarios. Similarly, in WY 1981, Scenario B1 has 34 fewer days below the 150 mg/L threshold than the existing condition (EBC2), but both years remain above the benchmark of 165 days. Thus, in both WY1979 and WY1981 at PP#1, water quality is degraded significantly for Scenario B1 as compared to existing conditions (EBC2), even though water quality objectives are met in both years.

Table 10 Number of years in the 16-year modeled record that the D-1641 WQO of 150 mg/L chloride for Municipal and Industrial Beneficial Uses is met at Antioch Water Works Intake, averaged by water year type, and based on DWR model results.[45]

Water Year Type	Total Years in Each Water Year Type	Number of Years 150 mg/L Chloride Threshold <u>is Met</u> at Antioch Water Works Intake		
		EBC2[b]	NAA[a]	B1[a]
Critical	5	0	0	0
Dry	4	0	0	0
Normal	3	0	0	0
Wet	4	3	1	1

[a] WaterFix model runs (05/2016)
[b] EIR/EIS model run EBC2 (2013), the existing condition model run most representative of current conditions

[45] The 150 mg/L threshold is evaluated on a calendar year basis, thus data were sorted by dominant water year classification and averaged for this analysis.

Table 11 Number of years in the 16-year modeled record that the D-1641 WQO of 150 mg/L chloride for Municipal and Industrial Beneficial Uses is met at PP#1, averaged by water year type, and based on DWR model results.

Water Year Type	Total Years in Each Water Year Type	Number of Years 150 mg/L Chloride Threshold is Met at PP#1		
		EBC2[b]	NAA[a]	B1[a]
Critical	5	4	3	3
Dry	4	4	3	4
Normal	3	2	3	3
Wet	4	3	3	4

[a] WaterFix model runs (05/2016)
[b] EIR/EIS model run EBC2 (2013), the existing condition model run most representative of current conditions

Table 12 Number of days per year in the 16-year modeled record that the D-1641 WQO of 150 mg/L chloride for Municipal and Industrial Beneficial Uses is met at PP#1 based on DWR model results. Bold numbers in gray cells indicate that the threshold criteria were not met.

Water Year	Threshold Criteria (days)	Number of Days 150 mg/L Chloride Threshold is Met at PP#1		
		EBC2 (days)	NAA (days)	B1 (days)
1976	155	291	366	301
1977	155	156	**145**	**112**
1978	190	243	239	**188**
1979	175	338	311	178
1980	190	**187**	202	242
1981	165	289	281	255
1982	240	299	298	287
1983	240	298	337	365
1984	240	366	357	366
1985	165	310	361	298
1986	240	**213**	**235**	254
1987	165	300	365	257
1988	155	217	263	250
1989	165	186	**159**	209
1990	155	164	165	168
1991	155	159	**132**	**138**

9.4. WaterFix Project operations will result in additional exceedances of E/I requirements.

D-1641 also includes a limitation on exports of water from the Delta (see Section 3.3). Specifically, D-1641 limits the amount of water that can be exported from the Delta to a fraction of the water that flows into the Delta. Currently, the export-to-inflow (E/I) ratio is defined to include all water exported from the Delta and all major freshwater inflows to the Delta; however, as noted in Section 3.3, DWR and Reclamation propose to redefine the E/I ratio such that the water diverted from the NDD would not be included in either the exports (E) or the inflows (I) used to evaluate this objective. The proposed new method of determining the E/I ratio would reduce the value of (E/I), such that more water could be exported from the Delta. Indeed, if only the NDD were used to export water, the value of the proposed new E/I ratio would be zero—in effect, any limitation on the fraction of inflows to the Delta that could be exported from the Delta would be eliminated.

Table 13 summarizes the number of days that the E/I ratio would be exceeded for each modeled scenario in the 16-year model period (5,832 days). The results show that including the number of exceedances of the (E/I) ratio is larger when the NDD water exports are included in both total exports and total inflows. In contrast, redefining the E/I ratio to exclude the amount of water exported from the NDD reduces the frequency with which the E/I ratio would be exceeded. For example, the B1 scenario exceeds the E/I ratio 850 days when the ratio is calculated to D-1641 specifications (i.e., to include all exports and all inflows) but only 270 days when the NDD is removed from the equation.

As shown in Table 13, exceedances of the E/I ratio occur in the existing condition (EBC2) and no action alternative (NAA). If the E/I ratio is evaluated for Scenario B1 using the same measure (i.e., including the water diverted from the NDD in both the exports and inflows), compliance with the E/I ratio declines with WaterFix. Excluding NDD exports and imports from the E/I ratio calculation has the effect of removing an important control on the amount of water exported from the Delta; it also has the effect of making it appear that the WaterFix Project will improve compliance with one of the many WQOs that apply to the Delta.

Table 13 Number of days the E/I ratio exceeds the threshold specified in the D-1641 WQOs for Municipal and Industrial Use for the 16-year modeled record, and overall percent of time in exceedance (in parentheses).

Scenario	Number of Days E/I Ratio Exceeds D-1641 Limits[d] (percent time ratio exceeds 35%)		
	EBC2[b,c]	**NAA[a,c]**	**B1[a]**
Redefined (E/I) excluding NDD flows	481 (8.2%)	349 (6.0%)	270 (4.6%)
D-1641 specifications	481 (8.2%)	349 (6.0%)	850 (14.6%)

[a] WaterFix model runs (05/2016)
[b] EIR/EIS model run EBC2 (2013), the existing condition model run most representative of current conditions
[c] Note that the E/I ratio calculations do not change for the NAA and EBC2 scenarios, because the NDD points do not exist for these scenarios.
[d] D-1641 limits Delta exports to 35% of Delta inflow between February and June (i.e., E/I < 0.35 from February-June), and to 65% of Delta inflow between July and January (i.e., E/I < 0.65 from July-January).

10. Opinion 6: The information provided in the Petition is insufficient for assessing the expected impacts of the WaterFix Project, but it appears that significant water quality degradation can be expected to occur.

Based on my experience and in consideration of the information presented by the petitioners, it is my opinion that the modeling and analysis presented by petitioners is not a sufficient or reasonable basis for assessing water quality degradation that will occur at the intake operated by the City of Antioch (a municipal drinking water supplier). As detailed throughout this report, there is a wide range in the potential operations of the proposed WaterFix Project; for example, petitioners note that some scenarios will result in 33% more freshwater being exported from the Delta, while other scenarios will result in 34% less freshwater being exported from the Delta. The range in potential water quality impacts is also broad. Although petitioners provide little certainty regarding anticipated project operations, they have stated that Scenario Boundary 1 (B1) is a suitable basis for evaluating impacts from the project.[46] My analysis of certain operations (most notably operations scenario B1) indicates that significant deterioration of water quality can be expected to occur at the City's intake as a result of the implementation of the WaterFix Project.

[46] Stated in Jennifer Pierre's oral testimony before the SWRCB on July 29, 2016.

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