WR-213

Rebuttal Testimony of Leslie Grober

Background

I have been an employee of the State Water Resources Control Board (State Water Board) since 2006, and I am currently employed by the State Water Board. Prior to 2006, I worked on water quality monitoring and modeling of the San Joaquin River system for the Central Valley Regional Water Quality Control Board beginning in 1994. I was the manager of the State Water Board's Hearings and Special Programs Section from April 2006 through May 2011. Since May 2011, I have been the Division of Water Rights' Assistant Deputy Director, overseeing the Hearings and Special Programs Branch. My priority programs include the State Water Board's San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta) Program, water rights hearings, water quality certifications of hydroelectric projects, and the development of flow objectives for priority tributaries. My number one priority is the review and update of the Bay-Delta Water Quality Control Plan (Bay Delta Plan). I hold a Master of Science degree in hydrologic sciences from the University of California, Davis, and a Bachelor of Science degree in geology from the State University of New York in Binghamton. A true and correct copy of my resume is Prosecution Team Exhibit WR-214.

As part of my responsibility for overseeing the review and update of the Bay Delta Plan, I am responsible for the modeling and review of modeling to assess the effects of changes in hydrology, and Central Valley Project (CVP) and State Water Project (SWP) (collectively projects) operations, on Delta water flow and water quality. I and my staff are familiar with Bay-Delta hydrology issues and have worked with modeling staff at the Department of Water Resources and United States Bureau of Reclamation regarding Delta hydrology and water quality.

Although I oversee the State Water Board's Bay-Delta and Hearings Section, I am separated by an ethical wall from the Hearings Section for these enforcement proceedings. It is my understanding that the Office of the Chief Counsel established the ethical wall and separation of functions upon commencement of litigation filed by various parties, including The West Side Irrigation District (WSID) in Sacramento Superior Court in June, 2015, which I understand has been coordinated into the California Water Curtailment Cases (JCCP 4838). I submitted a declaration as part of proceedings relating to WSID's request for a Temporary Restraining Order (TRO) in early July, 2015. The litigation was filed, and the TRO hearing took place, prior to these enforcement actions, although I understand that the ethical wall and separation of functions apply equally to the enforcement actions. I remain separated from the Hearings Section for purposes of these proceedings. Diane Riddle, Program Manager of the Bay-Delta & Hearings Section and direct supervisor of the Hearings Section, is serving in my place as necessary for these proceedings. I have not discussed these proceedings or the litigation with Ms. Riddle, the Hearings Section, the members of the Board, or any Board staff not designated on the "enforcement" side of the separation of functions. In order to assist me with any technical review necessary for the litigation and these enforcement proceedings, I have designated Tim Nelson of the Bay-Delta San Joaquin Unit as also on the "enforcement" side of the separation of functions. Although Mr. Nelson assisted me while preparing this testimony, I directed the preparation of the contents of this testimony, and performed or reviewed any necessary calculations myself.

Summary of Testimony

I have reviewed the testimony of Mr. Burke (Exhibit WSID-0123) and Dr. Paulsen (Exhibit BBID-388), as well as exhibits WSID-0124, WSID-0125, and BBID0384. I am familiar with the arguments advanced by Mr. Burke and Dr. Paulsen about the potential effect of prior conditions on Delta water quality and water availability. Review of similar year information, and the importance of prior month's conditions with and without the SWP and CVP, are the basis for their argument for water availability in June and beyond in 2015. Although not mentioned by name, this is the theory of the Delta Pool. This theory requires two key elements:

1. The channels and waterbodies in the Delta are below sea level so there is "always a supply of water"
2. These Delta waterbodies are "primed" with water from prior months such that water of a usable water quality (i.e. sufficiently low salinity so that the water can support irrigation of crops) is available to diverters in the Delta for some period of time after a discrete mass of water entered the Delta (or would have entered the Delta under some other condition, such as pre-SWP and CVP).

I am aware of no successful argument that refutes the conclusion that yes, indeed, there will always be water in the Delta or any other area that lies below sea level, and is connected to the sea. My testimony will therefore not significantly discuss or dispute that element of their testimony, with the exception of clarifying some assertions made regarding water levels.

The second element of their argument requires significant discussion. This element of Mr. Burke's and Dr. Paulsen's testimony hinges on the argument that the hydrology in 2015 was such that even if the CVP and SWP were not operating, WSID and BBID would have had a usable water supply. Their conclusions are drawn from two basic approaches at the problem:

1. The use of "similar year" information to show that during a year with hydrology similar to Water Year (WY) 2015, there was, in fact, usable water available to WSID and BBID if the projects were not operating
2. The use of models and source water fingerprinting to show that a sufficient quantity of water naturally flowed into the Delta in WY 2015 before June 2015, and would have provided a usable water supply in June and beyond even if the SWP and CVP were not operating.

The first approach is flawed because the pre-project years that were selected by Mr. Burke and Dr. Paulsen for the analysis are not sufficiently representative of WY 2015. In fact, WY 2015 is the worst year on record if one correctly considers the most important hydrology statistic, namely April through July flows. The similar year approach also does not take into account other changes in the basin, other than development of the CVP and SWP, so is not a sufficient indicator of water availability in 2015.

The second approach relies upon actual water quality conditions at WSID and BBID in 2015, and imposes on this actual water quality condition various incomplete qualitative and subjective assessments of what conditions would have been like if the CVP and SWP were not operating.

The most useful analysis and model run that would inform the matter of water availability was not submitted into evidence in this matter by either Mr. Burke or by Dr. Paulsen. This more useful model run was, however, previously analyzed by Mr. Burke in his declaration (WR-221[1]) submitted last summer in the WSID TRO proceedings that have since been coordinated into the California Water Curtailment Cases (JCCP 4838). Mr. Burke's evidence in that matter relied upon an analysis of 1977 as the next most relevant water year to support the conclusion that water is always available in the Delta at WSID's point of diversion. In my declaration for the WSID TRO proceedings (WR-220[2]), I augmented the analysis done by Mr. Burke to demonstrate that although there would always be water, the quality would not be suitable for any agricultural or municipal water supply purpose at the points of diversion of WSID and BBID in 2015, from June onward, if the CVP and SWP were not operating. Mr. Burke and now Dr. Paulsen have now shifted the focus to 1931 as next most relevant water year to make the same arguments.

In this testimony I defer to others on the prosecution team regarding the calculations made to determine water availability in 2015. Though the arguments made by Mr. Burke and Dr. Paulsen, to consider prior month's conditions to determine the availability of water in the Delta may, to some extent, have merit in other less dry years, conditions in 2015 were such that even if prior month's conditions and the absence of the CVP and SWP were considered, there would be no useful water available in June 2015 and beyond at the points of diversion of WSID and BBID.

Delta Water Levels: Single small diversions may not affect water levels but effects are cumulative

I agree with Mr. Burke and Dr. Paulsen that there will always be water in Delta channels that lie below sea level, as long as there is no physical obstruction in place, such as a dike or other barrier, which prevents sea water from flowing into those channels. In WSID-0123, item 9, Burke states: "Given the numerous withdrawals in the Delta, and the effect of the tides, water is always moving back and forth in the channels but the elevations of the water in the channels experience little change." This statement is misleading and unclear. In WSID-0125, a technical memorandum with the subject "WSID Diversion Analysis" Mr. Burke shows (in figure 3) changes in river stage of over 1.5 feet every day over a period of three days from 6/2/15 through 6/5/15, from a high of over 5.5 feet to a low less than 4.0 feet (NAVD). WSID figure 4 also shows that the bottom of the channel is - 7.0 feet (NAVD). The tides at Martinez over the same three days ranged from 6.75 feet to 0.50 feet (CDEC), datum NAVD88 as of 8/26/2005, (conversion to NGVDD29 is -2.68). A true and correct copy of tides at Martinez, accessed on CDEC, is Exhibit WR-243. Martinez tide information accessed on CDEC at: http://cdec.water.ca.gov/jspplot/jspPlotServlet.jsp?sensor_no=1811&end=06%2F05%2F2015+23%3A59&geom=huge&interval=4&cookies=cdec01

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[1] I reviewed Mr. Burke's Declaration as part of the TRO proceedings and I am familiar with its contents. Exhibit WR-221 is a true and correct copy of the Declaration of Thomas Burke in Support of Petitioners Ex Parte Application for Temporary Stay Re: Enforcement of Curtailment Notice (CCP § 1086 and/or 1094.5(g)) or in the Alternative Temporary Restraining Order and/or For Order to Show Cause Re: Preliminary Injunction (CCP §§ 525 et seq.)

[2] I prepared my Declaration as part of the TRO proceedings and I am familiar with its contents. Exhibit WR-220 is a true and correct copy of the Declaration of Leslie Grober in Opposition to Plaintiffs'/Petitioners' Ex Parte Application for Temporary Stay.

Mr. Burke used DSM2 to demonstrate that WSID diversions of 8 and 14 cfs do not affect water levels. I agree that pumping such a relatively small quantity of water from a relatively large channel will have no substantive observed effect. The correct conclusion should rather state: “Given the numerous withdrawals in the Delta, and the effect of the tides, water is always moving back and forth in the channels but the elevations of the water in the channels experience little change in response to a single, relatively small, diversion of 14 cfs.” Larger diversions, however, have been a cause of concern in the southern delta, in particular, which is why the diversion of water by the CVP and SWP in the southern Delta, have conditions in their water rights regarding study of, and maintenance of water levels (D-1641 [WR-231], page 150,151). Per D-1641: “Water levels in the southern Delta are affected by diversions at project export facilities, but are affected by other factors as well. The other factors include: low river flows entering the southern Delta canals; local channel depletions by agricultural diversions; natural tidal variations, especially during periods of extreme low tides; fluctuations in atmospheric pressure, local wind direction and velocity; and limited channel capacities.” (WR-231, page 102) This clarification is important because collectively, combined numerous local depletions, also contribute to changes in water level. These combined effects of numerous small diversions like that of WSID, or the single larger effect of SWP and CVP pumping, reduce water levels, and have the effect of drawing more fresh water into the southern Delta than would occur under a condition where there were no diversions whatsoever.

Previous Dry Years and Pre-project Conditions

There are at least two ways to arrive at a conclusion about what water quality would have been this year under “pre-project” conditions:

1. Rely upon empirical (observed) data for a year before the projects were built, in which hydrology and other conditions are similar to the current year; or
2. Model the current year with the effects of the projects removed

Neither of these methods were correctly applied by either Mr. Burke or Dr. Paulsen in the testimony or exhibits submitted for this proceeding.

Mr. Burke testifies that WSID 1931 and 1939 were drier than 2015, and water of adequate quality to support crops was available during the growing season of those years

Mr. Burke’s analysis (item 15 of WSID 123) relied upon empirical data (similar year data), by evaluating conditions purported to have occurred in 1931 and 1939, and DSM2 runs (WSID 123 item 16) to show “that a significant amount of Sacramento River water naturally entered into Old River over the summer” in those years. This use of data from years with similar characteristics can be a good way to draw conclusions about other similar years.

The conclusions were basically that water quality was sufficient in these pre-SWP and CVP years to support agriculture until “late in the year (end of the growing season)” (WSID 123 item 17). Burke also concluded that “significant Sacramento River water flows into Old River (WSID 123 item 18), and “(G)iven that the 1931 and 1939 water years were dryer than the 2014 and 2015 water years” it is

Burke's opinion that these years "provide a good, conservative proxy for determining water quality and availability at the WSID and BBID points of diversion during 2014 and 2015 without the influence of the Projects." (WSID 123 item 19) Burke goes on to state: "Given that no noticeable reduction in irrigation diversions were observed in 1931 or 1939, I would expect that the water quality in 2014 and 2015 would have been acceptable for irrigation as well, especially since they were not as dry as 1931 and 1939." (WSID 123 item 19). I will not explore whether or not conditions in these earlier years were such that they could support agriculture until late in the year because it is not necessary to do so.

There are two major flaws with Mr. Burke's line of reasoning:

1. 1931 and 1939 were not, in fact, drier than 2015 for the months in the unimpaired flow record that matter.
2. Use of similar year data does not assess other differences between the years, in this case separated by 76 to 84 years, a span over which a number of things, other than the SWP and CVP, have changed. Such changes include increased consumptive use by water rights holders senior to WSID and BBID, changed channel geometries in the Delta (such as increased volumes in the Sacramento and San Joaquin River deep water ship channels),and increased subsidence of Delta islands, to name a few.

It is also curious that Mr. Burke chose to abandon the analysis he did for WSID for the TRO proceedings in the litigation now coordinated as the California Water Curtailment Cases (JCCP 4838). In Mr. Burke's analysis prepared for the TRO proceedings (WR-221), he selected 1977 as a similar year to make the case that even in critically dry years there is water available at WSID's point of diversion. As will be shown, 1977 is a better year to draw conclusions about the current year.

Dr. Paulsen testifies that water of adequate quantity and quality would have been available to WSID and BBID in 2015 in the absence of the CVP and SWP because water was available to WSID and BBID in 1931, and conditions in 1931 are the most representative of the conditions that would have occurred during 2015 if the CVP and SWP did not exist

Dr. Paulsen's testimony suffers from the same misunderstanding and misuse of DWR's unimpaired flow data as Mr. Burke's testimony. WY 1931 is not sufficiently similar to WY 2015 to support conclusions about water availability and water quality, and assertions made contrary to this demonstrate a gross misunderstanding of how bad the water supply situation was in WY 2015.

Dr. Paulsen makes various assertions about water availability during other critically dry years, both before, and after development of the CVP and SWP. Table 4-2 on page 36 (pdf page 45) of BBID Exhibit 384 titled: "Top ten water years between 1906 and 2015, ranked by lowest runoff in the Sacramento and San Joaquin River Valleys (Eight-River FNF)." I verified that these are the ten lowest combined Sacramento and San Joaquin River runoff years based on the combined Sacramento Valley and San Joaquin Valley unimpaired flow record on CDEC (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST). A true and correct copy of this CDEC unimpaired flow record is Exhibit WR-244.

The years used by Dr. Paulsen for the data presented in Table 4-2 of BBID Exhibit 384 are sufficient to show how Dr. Paulsen's and Mr. Burke's analyses of this similar year hydrology are flawed. Care must be taken when assessing this dataset so as to not misinterpret the data, and thereby place undue significance on an incorrectly cited or used statistic. Examples of assertions made by Dr. Paulsen that misinterpret the statistics include:

> "WY 2015 was the seventh driest year on record in terms of the full natural flow, the fourth driest on record in terms of the Sacramento Valley water year index, and the driest on record in terms of the San Joaquin Valley index." (BBID-388, item 21(a)(vii) on page 9).
>
> "WY 1931 was the year with the lowest Sacramento River flow index in the historical record; because this year occurred during the pre-CVP/SWP time period, conditions during 1931 are most representative of the conditions that would (sic) occurred during WY 2015, if the CVP and SWP did not exist." (BBID-388, item 21(c)(i) on page 10).

These assertions rely upon incorrect use of unimpaired flow data because water year indices were used instead of the more important actual unimpaired flow, and the most critical time period was ignored:

- The unimpaired flow indices do not sufficiently weight the importance of April through July flows that are the subject of water availability in this matter.
- Both the Sacramento and San Joaquin WY indices are calculated using specific formulas that are based, in part, on the hydrology of the preceding year, so use of the index skews any analysis that is trying to draw conclusions about the natural flow available for the year in question, which in this case is WY 2015. The index should not be used unless one wants to take into account the potential that there is stored water remaining in project reservoirs from the preceding year, or, alternatively, to assess the dryness of the basin in the preceding year. The water year indices were developed as a simple means to determine the water year type (wet, above normal, below normal, dry, and critically dry), and based on that, the flow and other conditions for which the operators of the CVP and SWP (United States Bureau of Reclamation and Department of Water Resources, respectively) are responsible. The indices were therefore structured in a manner that weighted portions of the unimpaired flow record in the current and previous year so that *stored water and the storage of water was also considered.* The definition and calculation method for the Sacramento and San Joaquin River unimpaired flow indices are shown in figures 1 and 2 in D-1641 (WR-231, pages 190-191).

Dr. Paulsen also muddies the water with statements like: "However, distinctions between FNF and UF have been made in Bay-Delta office reports, where FNF is defined as a theoretical flow in a pre-development state, and UF is an estimated natural flow assuming consistent river configurations and the same groundwater accretion and depletion as in the historical condition (DWR 2011)" (BBID 384, page 35 (pdf page 44)). Though DWR (and others) have correctly made a distinction between natural flow and unimpaired flow, the usage on the CDEC website is such that FNF is the same as unimpaired flow. The point is that neither of these flows is the same as a "natural" flow condition because neither considers changes in channel geometry, and other physical changes in the system that have occurred as a result of development. As they are referred to on CDEC, and as presented in Dr. Paulsen's datasets, unimpaired flow and full natural flow are exactly the same thing.

To improve on Dr. Paulsen's evaluation of unimpaired flows, I analyze the unimpaired flow record for the ten years suggested by Dr. Paulsen. Ideally, because of the importance of the April through July timeframe, one would want to review the years that had the lowest April through July unimpaired flows. Those ten years are, in order from lowest to highest: 2015, 1977, 1924, 1931, 1934, 2014, 1976, 1987, 1988, and 2007. For the sake of comparing summary statistics with the statistics already submitted into the record, I have limited my analysis to the years selected by Dr. Paulsen.

Table 1 shows the Sacramento Valley Runoff and Water Year Index for the same dry and critical years, between 1906 and 2015, presented by Dr. Paulsen in Table 4-2 of BBID-384 (page 36 or pdf page 45). There are two important additions to these summary statistics that were not presented by either Mr. Burke or Dr. Paulsen:

1. April through July unimpaired flows
2. Previous year unimpaired flow

April through July unimpaired flow is the most relevant part of the unimpaired flow record, unless one wants to demonstrate the value of storing October through March precipitation in upstream reservoirs for later in the season. April through July includes the time period that the SWB prosecution team has demonstrated that natural flows were insufficient to meet all demands, including those of WSID and BBID. Dr. Paulsen's testimony regarding fingerprinting, discussed below, also demonstrates that Sacramento River flows prior to March contributed only a small fraction of the water available to WSID and BBID in June of 1931 and 2015. Per figure 6-12 in BBID-384, less than ten percent of the water at WSID intake in June had the March 2015 fingerprint. Figure 6-8 (BBID-384) shows that less than five percent of the water at WSID intake in June had the March 1931 fingerprint. This is particularly notable because March 1931 unimpaired flows were 1,199 taf, which is 357 taf (42 percent) higher than March 2015 unimpaired flows of 842 taf (BBID-384, appendix B).

The previous year's unimpaired flow provides a useful measure of "antecedent" conditions, meaning what happened prior to the water year in question. This information *is useful, and correctly used* in this context, because it provides an explicit indication of the dryness of preceding years that shows whether or not there was a potential shortage of water before the current year, and dry conditions in the water shed that could have the effect of reducing the effect of current year flows. This is distinct from "lumping" the assessment into the overall review of water year indices to draw conclusions about water availability in a single year without discretizing its parts so as to better understand the potential effects. It also correctly looks at the unimpaired flow of the preceding year, not the index.

Table 1. ***Sacramento Valley Runoff and Water Year Index for Select Dry and Critical Years between 1906 and 2015***

Sacramento Valley Runoff and Water Year Index for Select Dry and Critical Years between 1906 and 2015

Sacramento Valley

Water Year	Year Type	Previous Year Total Runoff	Runoff (MAF)				WY Index
			Oct-Mar	Apr-Jul	Aug-Sep[1]	Annual	
1924	C	13.21	3.27	1.94	0.53	5.74	3.87
1929	C	16.76	4.00	3.84	0.56	8.40	5.22
1931	C	13.52	3.52	2.09	0.49	6.10	3.66
1934	C	8.94	5.68	2.45	0.50	8.63	4.07
1939	D	31.83	4.56	3.04	0.58	8.18	5.58
1976	C	19.23	4.63	2.75	0.82	8.20	5.29
1977	C	8.2	2.49	1.93	0.70	5.12	3.11
1994	C	22.21	4.55	2.73	0.53	7.81	5.02
2014	C	12.19	4.29	2.59	0.58	7.46	4.07
2015	C	7.46	6.95	1.77	0.55	9.27	4.01

Years shown are the ten years with the lowest annual combined Sacramento and San Joaquin Valley runoff.

The 2015 WY index is based on measured unimpaired runoff for 2015; it differs slightly from the "official" WY index which is based on forecasted runoff values from May 2015.

[1] Value for August-September runoff was calculated by subtracting October-March runoff and April-June runoff from the annual total runoff.

Data from CDEC, accessed at http://cdec.water.ca.gov/cgi-progs/iodir?s=WSIHIST

Although WY 1931 had the lowest pre-CVP/SWP Sacramento River Index, and one of the lowest annual unimpaired flows (WY 1924 was lower), WY 2015 had the lowest April through July flows in this ten year dataset, and in the 1906 to 2015 record (Table 1). WY 2015 also had the lowest prior year unimpaired flow. Table 2 compares all the summary statistics between 2015 and the other nine years. The cells shaded red mean that the water year had a worse (drier) statistic than 2015. The cells shaded green mean that the subject year was better (wetter) than 2015 for that statistic. April through July unimpaired flow was 0.32 million acre-feet (320,000 acre-feet) lower in WY 2015 than in WY 1931; this is 15 percent lower than WY 1931. The prior year's unimpaired flow was 6.06 million acre-feet lower (45 percent) in WY 2015 than the year prior to WY 1931.

Table 2. Sacramento Valley Runoff and Water Year Index in 2015 Compared with Select Dry and Critical Years between 1906 and 2014

Sacramento Valley Runoff and Water Year Index in 2015 Compared with Select Dry and Critical Years between 1906 and 2014

Sacramento Valley

Water Year	Year Type	Previous Year Total Runoff	Runoff (MAF)				WY Index
			Oct-Mar	Apr-Jul	Aug-Sep[1]	Annual	
2015	C	7.46	6.95	1.77	0.55	9.27	4.01
Difference compared to 2015							
1924	C	5.75	-3.68	0.17	-0.02	-3.53	-0.14
1929	C	9.3	-2.95	2.07	0.01	-0.87	1.21
1931	C	6.06	-3.43	0.32	-0.06	-3.17	-0.35
1934	C	1.48	-1.27	0.68	-0.05	-0.64	0.06
1939	D	24.37	-2.39	1.27	0.03	-1.09	1.57
1976	C	11.77	-2.32	0.98	0.27	-1.07	1.28
1977	C	0.74	-4.46	0.16	0.15	-4.15	-0.90
1994	C	14.75	-2.40	0.96	-0.02	-1.46	1.01
2014	C	4.73	-2.66	0.82	0.03	-1.81	0.06

Years compared to 2015 are the nine years with the lowest annual combined Sacramento and San Joaquin Valley runoff between 1906 and 2014.

The 2015 WY index is based on measured unimpaired runoff for 2015; it differs slightly from the "official" WY index which is based on forecasted runoff values from May 2015.

[1] Value for August-September runoff was calculated by subtracting October-March runoff and April-June runoff from the annual total runoff.

Data from CDEC, accessed at http://cdec.water.ca.gov/cgi-progs/iodir?s=WSIHIST

Tables 3 and 4 provide the same information for the San Joaquin Valley unimpaired flow. April through July unimpaired flow was 0.44 million acre-feet (440,000 acre-feet) lower in WY 2015 than in WY 1931; this is 37 percent lower than WY 1931. The prior year's index was 1.53 million acre-feet (47 percent) lower in WY 2015 than WY 1931. The annual unimpaired flow was also 0.23 million acre-feet (14 percent) lower in WY 2015 than in WY 1931.

Table 3. San Joaquin Valley Runoff and Water Year Index for Select Dry and Critical Years between 1906 and 2015

San Joaquin Valley Runoff and Water Year Index for Select Dry and Critical Years between 1906 and 2015

San Joaquin Valley

Water Year	Year Type	Previous Year Total Runoff	Runoff (MAF)				WY Index
			Oct-Mar	Apr-Jul	Aug-Sep[1]	Annual	
1924	C	5.51	0.45	1.03	0.02	1.50	1.42
1929	C	4.37	0.52	2.29	0.03	2.84	2.00
1931	C	3.25	0.46	1.18	0.02	1.66	1.20
1934	C	3.34	0.98	1.26	0.04	2.28	1.44
1939	D	11.24	1.00	1.83	0.07	2.90	2.20
1976	C	6.18	0.78	1.07	0.12	1.97	1.57
1977	C	1.97	0.22	0.80	0.03	1.05	0.84
1994	C	8.38	0.66	1.80	0.08	2.54	2.05
2014	C	3.05	0.46	1.21	0.05	1.72	1.16
2015	C	1.72	0.66	0.74	0.03	1.43	0.81

Years shown are the ten years with the lowest annual combined Sacramento and San Joaquin Valley runoff.

The 2015 WY index is based on measured unimpaired runoff for 2015; it differs slightly from the "official" WY index which is based on forecasted runoff values from May 2015.

[1] Value for August-September runoff was calculated by subtracting October-March runoff and April-June runoff from the annual total runoff.

Data from CDEC, accessed at http://cdec.water.ca.gov/cgi-progs/iodir?s=WSIHIST

Table 4. San Joaquin Valley Runoff and Water Year Index in 2015 Compared with Select Dry and Critical Years between 1906 and 2014

San Joaquin Valley Runoff and Water Year Index in 2015 Compared with Select Dry and Critical Years between 1906 and 2014

San Joaquin Valley

Water Year	Year Type	Previous Year Total Runoff	Runoff (MAF)				WY Index
			Oct-Mar	Apr-Jul	Aug-Sep[1]	Annual	
2015	C	1.72	0.66	0.74	0.03	1.43	0.81
Difference compared to 2015							
1924	C	3.79	-0.21	0.29	-0.01	0.07	0.61
1929	C	2.65	-0.14	1.55	0.00	1.41	1.19
1931	C	1.53	-0.20	0.44	-0.01	0.23	0.39
1934	C	1.62	0.32	0.52	0.01	0.85	0.63
1939	D	9.52	0.34	1.09	0.04	1.47	1.39
1976	C	4.46	0.12	0.33	0.09	0.54	0.76
1977	C	0.25	-0.44	0.06	0.00	-0.38	0.03
1994	C	6.66	0.00	1.06	0.05	1.11	1.24
2014	C	1.33	-0.20	0.47	0.02	0.29	0.35

Years compared to 2015 are the nine years with the lowest annual combined Sacramento and San Joaquin Valley runoff between 1906 and 2014.

The 2015 WY index is based on measured unimpaired runoff for 2015; it differs slightly from the "official" WY index which is based on forecasted runoff values from May 2015.

[1] Value for August-September runoff was calculated by subtracting October-March runoff and April-June runoff from the annual total runoff.

Data from CDEC, accessed at http://cdec.water.ca.gov/cgi-progs/iodir?s=WSIHIST

Tables 5 and 6 provide the same information for the Combined Sacramento and San Joaquin Valley unimpaired flow. April through July unimpaired flow was 0.76 million acre-feet (760,000 acre-feet) lower in WY 2015 than in WY 1931; this is 23 percent lower than WY 1931. The prior year's combined unimpaired flow was 7.59 million acre-feet (45 percent) lower in WY 2015 than WY 1931.

Table 5. Combined Sacramento and San Joaquin Valley Runoff and Water Year Index for Select Dry and Critical Years between 1906 and 2015

Combined Sacramento and San Joaquin Valley Runoff and Water Year Index for Select Dry and Critical Years between 1906 and 2015

Combined Sacramento and San Joaquin Valleys

Water Year	Year Type	Previous Year Total Runoff	Runoff (MAF)				WY Index
			Oct-Mar	Apr-Jul	Aug-Sep[1]	Annual	
1924	C	18.72	3.72	2.97	0.55	7.2	5.29
1929	C	21.13	4.52	6.13	0.59	11.2	7.22
1931	C	16.77	3.98	3.27	0.51	7.8	4.86
1934	C	12.28	6.66	3.71	0.54	10.9	5.51
1939	D	43.07	5.56	4.87	0.65	11.1	7.78
1976	C	25.41	5.41	3.82	0.94	10.2	6.86
1977	C	10.17	2.71	2.73	0.73	6.2	3.95
1994	C	30.59	5.21	4.53	0.61	10.4	7.07
2014	C	15.24	4.75	3.80	0.63	9.2	5.23
2015	C	9.18	7.61	2.51	0.58	10.7	4.82

Years shown are the ten years with the lowest annual combined Sacramento and San Joaquin Valley runoff.

The 2015 WY index is based on measured unimpaired runoff for 2015; it differs slightly from the "official" WY index which is based on forecasted runoff values from May 2015.

[1] Value for August-September runoff was calculated by subtracting October-March runoff and April-June runoff from the annual total runoff.

Data from CDEC, accessed at http://cdec.water.ca.gov/cgi-progs/iodir?s=WSIHIST

Table 6.Combined Sacramento and San Joaquin Valley Runoff and Water Year Index for2015 Compared with Select Dry and Critical Years between 1906 and 2014

Combined Sacramento and San Joaquin Valley Runoff and Water Year Index in 2015 Compared with Select Dry and Critical Years between 1906 and 2014

Combined Sacramento and San Joaquin Valleys

Water Year	Year Type	Previous Year Total Runoff	Runoff (MAF)				WY Index
			Oct-Mar	Apr-Jul	Aug-Sep[1]	Annual	
2015	C	9.18	7.61	2.51	0.58	10.70	4.82
Difference compared to 2015							
1924	C	9.54	-3.89	0.46	-0.03	-3.46	0.47
1929	C	11.95	-3.09	3.62	0.01	0.54	2.40
1931	C	7.59	-3.63	0.76	-0.07	-2.94	0.04
1934	C	3.1	-0.95	1.2	-0.04	0.21	0.69
1939	D	33.89	-2.05	2.36	0.07	0.38	2.96
1976	C	16.23	-2.20	1.31	0.36	-0.53	2.04
1977	C	0.99	-4.90	0.22	0.15	-4.53	-0.87
1994	C	21.41	-2.40	2.02	0.03	-0.35	2.25
2014	C	6.06	-2.86	1.29	0.05	-1.52	0.41

Years compared to 2015 are the nine years with the lowest annual combined Sacramento and San Joaquin Valley runoff between 1906 and 2014.

The 2015 WY index is based on measured unimpaired runoff for 2015; it differs slightly from the "official" WY index which is based on forecasted runoff values from May 2015.

[1] Value for August-September runoff was calculated by subtracting October-March runoff and April-June runoff from the annual total runoff.

Data from CDEC, accessed at http://cdec.water.ca.gov/cgi-progs/iodir?s=WSIHIST

Not only was there 760,000 acre-feet less water in April through July of WY 2015 than WY 1931, the unimpaired flows prior to that period occurred mostly in December 2014 and February 2015. Table 7 shows the monthly full natural flows based on the Eight-River Unimpaired Runoff index assembled in BBID-384 Appendix B. Table 7 has the data only for the same ten years presented above, and used by Dr. Paulsen, and adds summary rows and a column that shows the difference between WY 2015 and WY 1931 full natural flows. Eight-River index flows were lower in March, April, and May of 2015 than in 1931, and only slightly higher in June. The sum of March through June Eight-River index flows was 1,170 taf (28 percent) lower in 2015 than in 1931. Though adding February to the total makes the years seem similar, DSM2 model runs and the Martinez EC versus Delta outflow chart below (see Figure 8 on page 26), shows that even this large quantity of water in February is effectively lost from the system, under any conditions, by June 2015.

Table 7. Full Natural Flow record from BBID-384, Appendix B

WY	Min	1924	1929	1931	1934	1939	1976	1977	1994	2014	2015	1934 minus 2015
Oct	315	454	334	343	315	601	916	416	512	365	362	-19
Nov	357	422	523	466	357	645	858	418	430	361	463	3
Dec	377	488	636	389	1,041	797	763	379	777	377	2,905	-2,516
Jan	368	557	613	802	1,466	792	648	475	776	368	806	-4
Feb	476	1,158	1,123	775	1,593	814	877	476	1,229	1,224	2,228	-1,453
Mar	545	635	1,289	1,199	1,895	1,906	1,342	545	1,486	2,052	842	357
Apr	689	1,068	1,628	1,235	1,615	2,259	1,351	689	1,567	1,712	767	468
May	829	1,096	2,490	1,182	1,092	1,471	1,436	906	1,790	1,182	829	353
Jun	449	449	1,455	541	656	723	607	755	806	552	549	-8
Jul	307	357	555	307	349	418	425	378	366	369	336	-29
Aug	263	282	297	263	277	319	500	335	280	327	293	-30
Sep	252	270	303	252	257	339	450	402	328	298	292	-40
Mar-Jun	2,895	3,248	6,862	4,157	5,258	6,359	4,736	2,895	5,649	5,498	2,987	1,170
Feb-Jun	3,371	4,406	7,985	4,932	6,851	7,173	5,613	3,371	6,878	6,722	5,215	-283
Eight-River Unimpaired Runoff Index from Paulsen BBID -384, appendix B												

Tables 8 and 9 show that the combined Sacramento and San Joaquin Valley four-year average unimpaired flows was about one million acre-feet lower in 2015 than in 1931-- four million acre-feet lower over four years. The April through June period was about 900 taf lower in 2015 than in 1931—3.6 million acre-feet lower over four years. This shows that not only was 2015 the worst on record with regard to April through July flows, it was also the worst on record in terms of April through July conditions for the three prior years.

Table 8. Combined Sacramento and San Joaquin Valley 4 Year Avg. Runoff and Water Year Index for Select Dry and Critical Years between 1906 and 2015

Combined Sacramento and San Joaquin Valley 4 Year Avg. Runoff and Water Year Index for Select Dry and Critical Years between 1906 and 2015

Combined Sacramento and San Joaquin Valleys

Water Year	Selected Year Type	4 Year Average Runoff (MAF)				4 Year Avg. WY Index
		Oct-Mar	Apr-Jul	Aug-Sep[1]	Annual	
1924	C	7.90	6.58	0.71	15.18	7.28
1929	C	8.74	5.81	0.64	15.19	7.19
1931	C	6.50	4.11	0.59	11.20	5.76
1934	C	4.80	3.86	0.54	9.20	4.46
1939	D	9.59	7.41	0.68	17.67	8.21
1976	C	12.09	6.97	0.94	20.00	9.05
1977	C	9.51	5.85	0.90	16.26	7.69
1994	C	6.58	4.66	0.60	11.83	5.46
2014	C	7.80	5.65	0.73	14.18	6.83
2015	C	6.36	3.21	0.62	10.19	5.20

Years shown are the ten years with the lowest annual combined Sacramento and San Joaquin Valley runoff. Values are averaged for the selected year plus the previous three years.

[1] Value for August-September runoff was calculated by subtracting October-March runoff and April-June runoff from the annual total runoff.
Data from CDEC, accessed at http://cdec.water.ca.gov/cgi-progs/iodir?s=WSIHIST

Table 9. Combined Sacramento and San Joaquin Valley 4 Year Avg. Runoff and Water Year Index in 2015 Compared with Select Dry and Critical Years between 1906 and 2014

Combined Sacramento and San Joaquin Valley 4 Year Avg. Runoff and Water Year Index in 2015 Compared with Select Dry and Critical Years between 1906 and 2014

Combined Sacramento and San Joaquin Valleys

Water Year	Selected Year Type	4 Year Average Runoff (MAF)				4 Year Avg. WY Index
		Oct-Mar	Apr-Jul	Aug-Sep[1]	Annual	
2015	C	6.36	3.21	0.62	10.19	5.20
Difference compared to 2015						
1924	C	1.53	3.37	0.09	4.99	2.08
1929	C	2.38	2.60	0.02	5.00	1.99
1931	C	0.14	0.90	-0.03	1.01	0.56
1934	C	-1.56	0.65	-0.09	-0.99	-0.74
1939	D	3.22	4.20	0.06	7.48	3.01
1976	C	5.73	3.76	0.32	9.81	3.85
1977	C	3.15	2.65	0.28	6.07	2.49
1994	C	0.21	1.46	-0.02	1.64	0.26
2014	C	1.43	2.44	0.11	3.99	1.63

Years compared to 2015 are the nine years with the lowest annual combined Sacramento and San Joaquin Valley runoff between 1906 and 2014. Values are averaged for the selected year plus the previous three years.

[1] Value for August-September runoff was calculated by subtracting October-March runoff and April-June runoff from the annual total runoff.
Data from CDEC, accessed at http://cdec.water.ca.gov/cgi-progs/iodir?s=WSIHIST

Dr. Paulsen testifies that she "reviewed and analyzed model results for the WY 1931 and the WY 2015 runs to develop an opinion regarding conditions that would have existed during WY 2015 if the CVP and SWP had not been operating" (BBID-388, page 7, item20 (c)(iii))

Dr. Paulsen incorrectly assumes that WY 1931 is representative of WY 2015. As shown above, this assumption is incorrect, so no conclusions about water availability in WY 2015 can be drawn from that aspect of the analysis. Model runs made and analyzed by Dr. Paulsen for WY 2015 were based on the actual operation of the SWP and CVP, so these model runs only show what water quality was like with the projects operating. Dr. Paulsen uses fingerprinting and the particle tracking element of DSM2 to determine that water at the BBID's point of diversion was sourced from the Sacramento River, and was of adequate quality to support agricultural uses, and also that supply and quality would have been adequate if the CVP and SWP had not been operating. The last element of Dr. Paulsen's argument, about also being of adequate quantity and quality from the Sacramento River had the CVP and SWP not been operating, is an unfounded assertion that relies upon unfounded and incorrect inferences and assumptions about what would have been the condition absent the operation of the CVP and SWP.

Volumetric fingerprinting

Page 75 of Dr. Paulsen's technical report (BBID-384) states: "In addition, the DSM2 model includes a feature called 'volumetric fingerprinting,' which tracks 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."

I agree that DSM2 and volumetric fingerprinting can be a useful tool to determine how much water from different sources and times arrives at different locations in the Delta, however, the underlying assumptions and the model must be used correctly to obtain true and correct conclusions. As will be shown, there also appear to be limits on the hydrologic conditions for which DSM2 can be used to obtain reliable results.

Dr. Paulsen relies upon volumetric fingerprinting, an element of DSM2, to determine that:

- During June 13-25, 2015 water at BBID intake consisted primarily of Sacramento River water that entered the Delta during the months of February-May 2015
- Water that entered the Delta from the Sacramento River consisted of full natural flow prior to about April 20, 2015, and mixed natural flow and stored water released after April 20.
- Project reservoirs upstream of the Delta captured and stored a portion of the runoff that occurred during the wet months of 2015; and some fraction of this water would have remained in the Delta in subsequent months.
- Less than 20% of the water at Clifton Court Forebay in late June 2015 flowed into the Delta from the Sacramento River after April 20, 2015, and only a fraction of that water would have been stored water released from reservoirs upstream of the delta (items ii, iii, iv and v of section 21(f)

Dr. Paulsen concludes: "Source fingerprinting performed using the DSM2 model demonstrates that the majority of water diverted by BBID between June 13-25, 2015, consisted of the full natural flow of the Sacramento River that entered the Delta many months prior to that time." (BBID388, section 21(f)(vi) on page 13)

Though the above assertion may be generally correct, the associated analysis is muddled and the conclusions of how this relates to a condition without the operations of the SWP and CVP in WY 2015 are wrong. Before providing the basis for this determination, it is useful to take a step back and understand what is fundamentally going on in the Delta.

In BBID 388 (page 8 section 21(a)(v)), Dr Paulsen states: "The volume of water in the Delta is large (the Delta contains approximately 1.2 million acre-feet (MAF) of water), and the residence time of water within the Delta varies from a few days during the winter of wet years to as long as three months during the summer and fall of dry years."

Simple Residence Times are Insufficient Indicators of Water Quality

Dr. Paulsen discusses residence times, presents results of DSM2 model runs, and then draws conclusions about an alternative situation if the projects were not operating. There is little discussion of mixing and where this mixing occurs, and how that would affect modeled and actual water qualities if the projects were not operating. Although important, simple volumes, and estimates of residence times cannot provide a sufficient answer regarding water availability and quality in the Delta. Mixing of water, particularly in Suisun Bay, makes the mixed water from that source too salty for beneficial use far earlier than simple residence times and fingerprinting, without considering the effects of even small volumes of very saline water, would suggest. For example, fully half of the water at a particular location could come from water that entered from the Sacramento River spanning several months, but if the other half came from Suisun Bay, with an EC say of 20,000 us/cm, the water would have an EC of just over 10,000 us/cm, and would be unusable for almost all purposes.

To improve hydrodynamic models in the Delta, the USGS and San Francisco Bay Estuary Inter-Agency Ecological Program (IEP) sponsored the development of a 10 meter horizontal grid of bathymetry in the Delta. (USGS, 2007 http://sfbay.wr.usgs.gov/sediment/delta/index.html). A true and correct copy of the USGS conclusions and channel volumes is Exhibit WR-245.

The survey determined the volume and area for various regions of the Delta shown in figure 1. I have added several place names, in red) to help in the discussion.

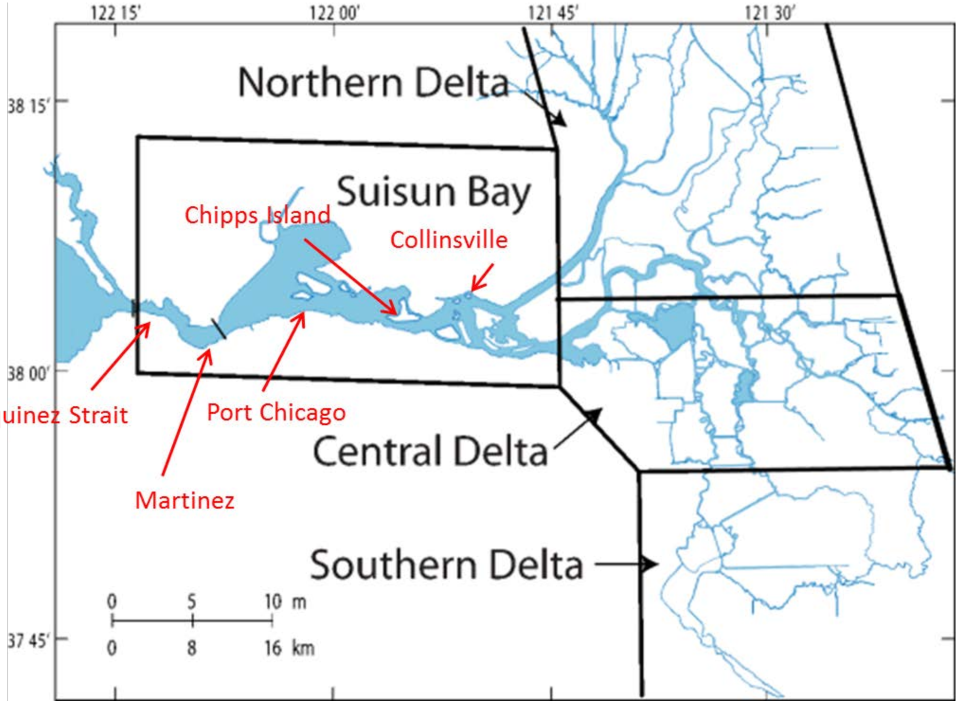


Figure 1. Copy of Figure 11 from USGS, 2007 (http://sfbay.wr.usgs.gov/sediment/delta/results.html), with approximate locations of D-1641 Delta outflow "X2" compliance locations and other points of interest added in red

Table 10 has the summary areas and volumes from the USGS report, with a conversion to volumes in taf, and tidal flux based on an assumed a 2.2 foot tidal range over the entire area. This assumption of 2.2 feet over the entire area is, of course, not correct because, as Dr. Paulsen correctly describes, tidal variation is greatest to the west in Suisun Bay, and decreases in the eastern, northern, and southern parts of the Delta. To determine the actual tidal fluxes at any specific location requires consideration of the actual geographically variable tidal range in each of the areas landward of the specific location. The 2.2 foot reference is however, useful to bracket a realistic tidal flux because different numbers are provided by Mr. Burke and Dr. Paulsen. Dr. Paulsen provides a figure from a DWR report in BBID-384 (figure 4-4 on page 30) that shows a tidal flux of 340,000 cfs (which corresponds to approximately 680 taf) in eastern Suisun Bay. Mr. Burke says: “Over a typical cycle during the summer months approximately 170,000 acre feet of water moves into the Delta twice each day (WSID-0123, page 3, item 8). At twice per day this would be equivalent to approximately 340 taf per day. For the sake of general argument I think it is reasonable to conclude that the daily tidal flux in western Suisun Bay is approximately 340 taf per day, as Mr. Burke says. Precise determination of the tidal flux is not necessary to demonstrate the massive flow and water quality effects that any tidal flux within this range has in the Delta.

Table 10. Delta and Suisun Bay Channel Volumes

Region	**Area (million meters^2)**	**Volume (million meters^3)**	**Area (acres)**	**Volume (TAF)**	**Tidal Flux (TAF)**
Suisun Bay	165	954	40,772	773	179
North Delta	74	407	18,286	330	80
Central Delta	66	267	16,309	216	72
South Delta	10	28	2,471	23	11
Total	316	1,656	78,085	1,343	344
Total (w/o Suisun)	150	702	37,066	569	163
Areas and volumes from: http://sfbay.wr.usgs.gov/sediment/delta/conclusions.html tidal flux assumes twice daily 2.2 foot tidal range in all areas					

The value of the data in table 10 is that it breaks down the monolith of “the Delta” into important separate pieces from which one can draw reasonable conclusions of residence times and the potential water quality effects of removing the operation of the CVP and SWP. Dr. Paulsen alludes to this in BBID384: “Deep water channels that were dredged for shipping and navigation purposes also affect Delta hydrodynamics and flow. Channels were widened and deepened to create the Stockton and Sacramento Deep Water Ship Channels, which changed freshwater flow dynamics in the Sacramento and San Joaquin Rivers and subsequently altered tidal flow volumes and increased seawater dispersion by increasing the volume of water in the Delta (CCWD 2010).” (BBID-384 page 25, pdf page 34). These large channels, not present in their current form in 1931, are part of the reason that channel volumes are so much bigger in the northern and Central Delta.

Table 10 may suggest, based on residence times alone, that a pool of water in Suisun Bay and the Delta could provide a prolonged Delta water supply. In contrast, table 10 also suggests that the entire volume of Suisun Bay is exchanged by the tides over less than three days (3 x 340 taf = 1,020 taf, which is greater than 773 taf). Table 11 provides additional volumes of water that can be compared and contrasted with Delta and Suisun Bay channel volumes: delta outflow and combined SWP and CVP exports (from CDEC, in WR-246), and Delta gross channel depletions used in DAYFLOW (WR-247). A true and correct copy of CDEC data for Delta outflow, SWP and CVP exports, and EC at Martinez is Exhibit WR-246. A true and correct copy of DAYFLOW Delta channel depletions is Prosecution Team Exhibit WR-247.

If one takes the total 1.343 taf volume of the Delta and Suisun Bay, one may be tempted to conclude that there is a six month supply of water based on June DAYFLOW Delta gross channel depletions of 223 taf/month (223/1343); and if one excludes Suisun Bay there is still a 2.5 month supply (569/223). This is, of course, incorrect because it does not take into account the substantial mixing that occurs due to the extremely high tidal flux, relative to inflow. As stated above, the daily tidal flux is approximately 340 taf/day. This means that 340,000 acre-feet of water per day flows from San Pablo Bay into Suisun Bay and the Delta, and back again. This greatly exceeds the daily Delta inflow and net daily Delta Outflow in all but extreme high flow events. Net Delta outflow ranged from 1,971 taf/month in December 2014 (average of 64 taf/day) to 229 taf/month (8 taf/day average) in June 2015 (Table11).

Table 11. Monthly Delta Outflow, Combined SWP and CVP Exports, and Delta Gross Channel Depletions.

Monthly Delta Outflow, Combined SWP and CVP Exports, and Delta Gross Channel Depletions

Month	Total Delta Outflow (TAF)	Combined SWP and CVP Exports (taf)	Delta Gross channel depletions (taf)
Oct-14	258	66	114
Nov-14	307	173	103
Dec-14	1,971	396	128
Jan-15	388	315	74
Feb-15	880	276	51
Mar-15	306	177	80
Apr-15	319	86	112
May-15	317	50	149
Jun-15	229	39	223
Jul-15	211	36	267
Aug-15	186	75	232
Sep-15	214	125	156

Delta outflow and export data from CDEC, accessed on February 19, 2015 at http://cdec.water.ca.gov/misc/dailyStations.html

Delta Cross Channel Depletions from DAYFLOW, accessed on February 19, 2015 at: http://www.water.ca.gov/dayflow/documentation/table3.cfm

Figure 2 uses the volumes in table 2, and presents them in a scaled schematic representation of Suisun Bay and the northern, central, and southern Delta. The figure shows the four regions of the Delta scaled according to their channel volumes. Superimposed on that graphic is a scaled representation of the 340 taf/day tidal flux. This figure makes two things more visually clear:

1. The importance of tidal flux compared to the total volume of Suisun Bay and the Delta
2. The relatively small volume of water in southern Delta channels

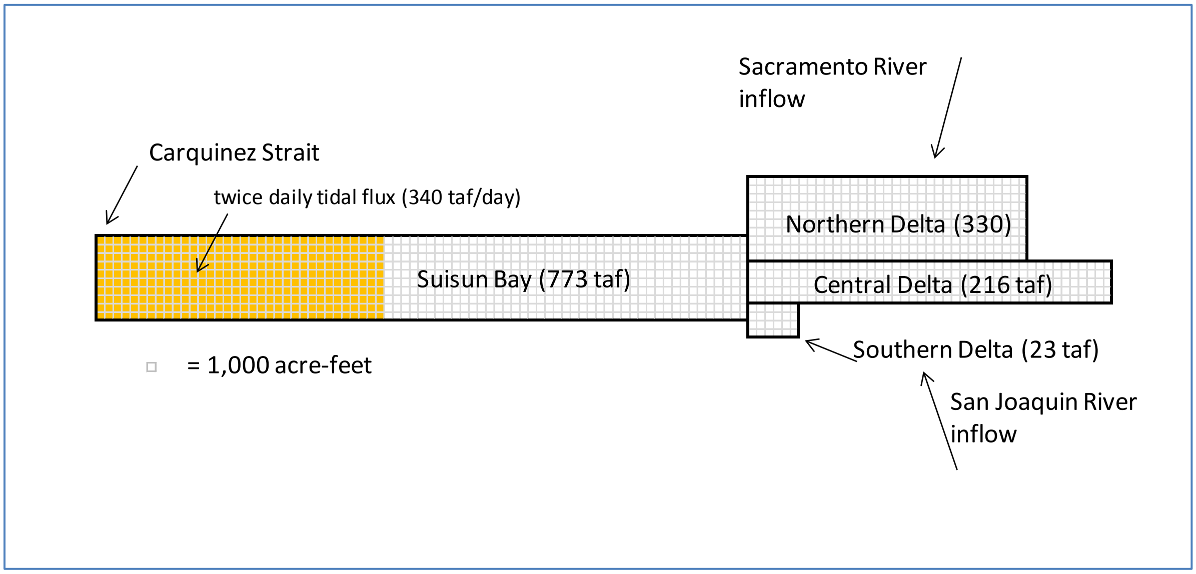


Figure 2. Schematic of Suisun Bay and the Delta with scaled channels volumes

Figure 3, below, adds the following elements to the above figure 2:

- Net Delta outflow component of 8 taf per day (equivalent roughly to 4,000 cfs in June 2015);
- June Delta gross channel depletions of 223 taf/month, distributed unevenly across the northern, central, and southern Delta; and
- Combined SWP and CVP June exports of 39 taf from their facilities in the southern Delta

This shows that although roughly one third of the consumptive use that contributes to gross channel depletions occurs in the southern delta (this is a rough estimate based on relatively similar geographic areas), the southern Delta channel volume can accommodate only 23 taf of the 78 taf/mo, if split evenly, per area. The 223 taf/mo gross channel depletions is based on June DAYFLOW Delta gross channel depletions. This figure shows how the southern Delta can accommodate little of the storage that may occur in the Delta—the water comes from elsewhere. This also shows that in June alone the SWP and CVP exported a volume of water that exceeds channel volumes in the southern Delta by more than 50 percent.

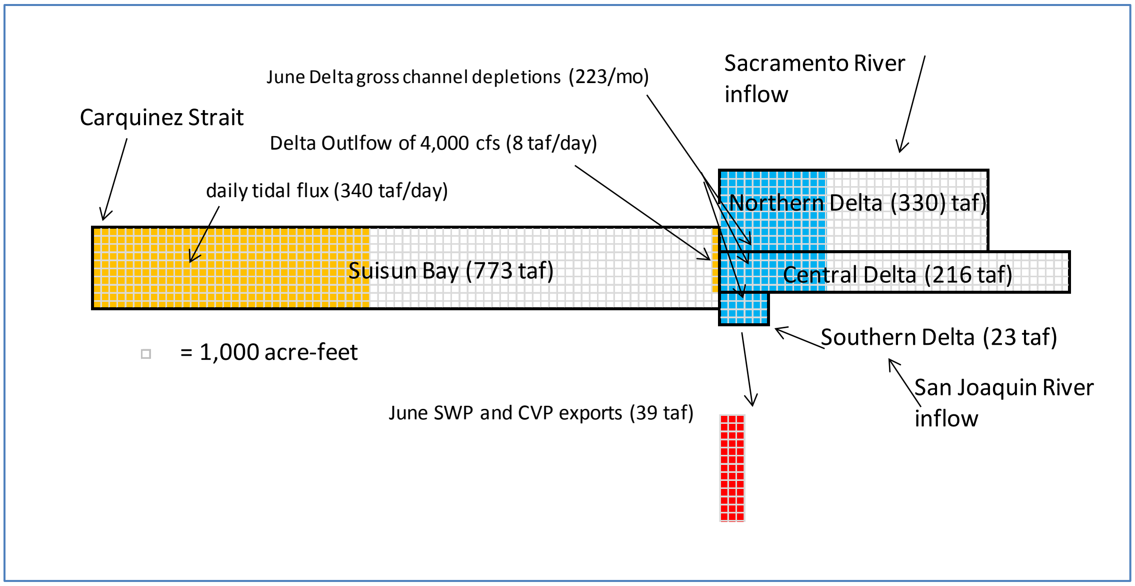


Figure 3. Schematic of Suisun Bay and the Delta with scaled channels volumes and June conditions

Figure 4, below, shows conditions prior to June. These conditions are even more interesting because they show how big the flow volumes exported by the CVP and SWP are in relation to Delta channel volumes. The movement of this large quantity of water has the effect of insulating the southern Delta, in particular, from the effects of tidal and water quality influences from Suisun Bay. That is why the DSM2 fingerprints show such a large quantity of pre-June water available in the southern Delta in June 2015. This is water that would not have been filling the southern Delta channels to the same extent, and later be available, if the SWP and CVP were not exporting water.

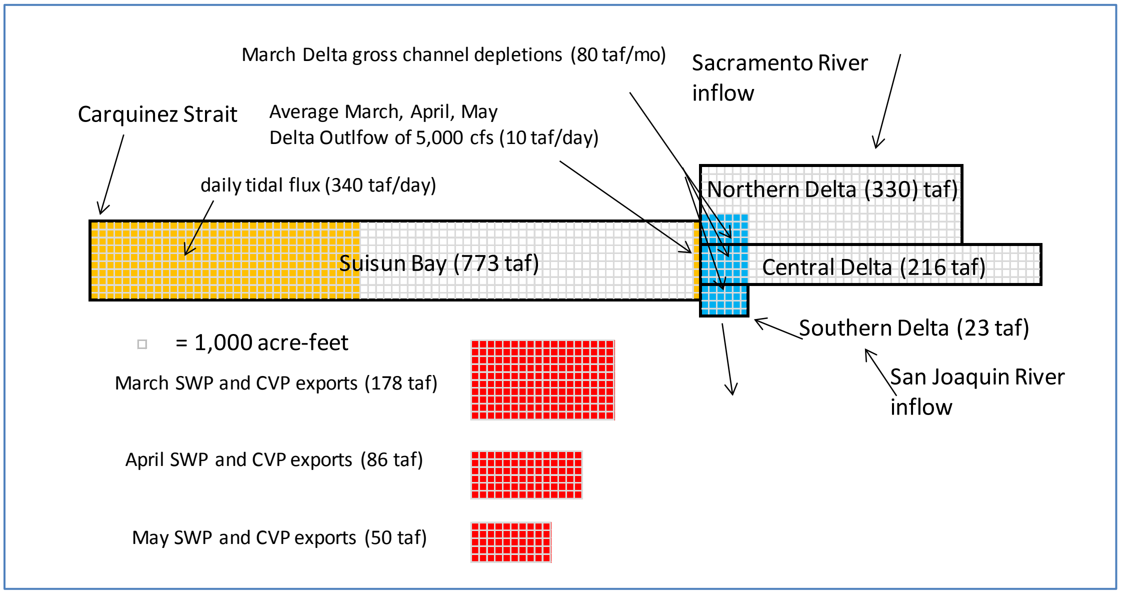


Figure 4. Schematic of Suisun Bay and the Delta with scaled channels volumes and pre-June conditions

Before commencing an analysis of Dr. Paulsen's DSM2 model runs and volumetric fingerprint runs it is important to confirm, or not, the validity of Dr. Paulsen's WY 2015 DSM2 model results to speak to conditions in WY 2015. Figure 5 is the chart Dr. Paulsen presents showing how the DSM2 model performs in 2015 with regard to calculation of EC at Clifton Court.

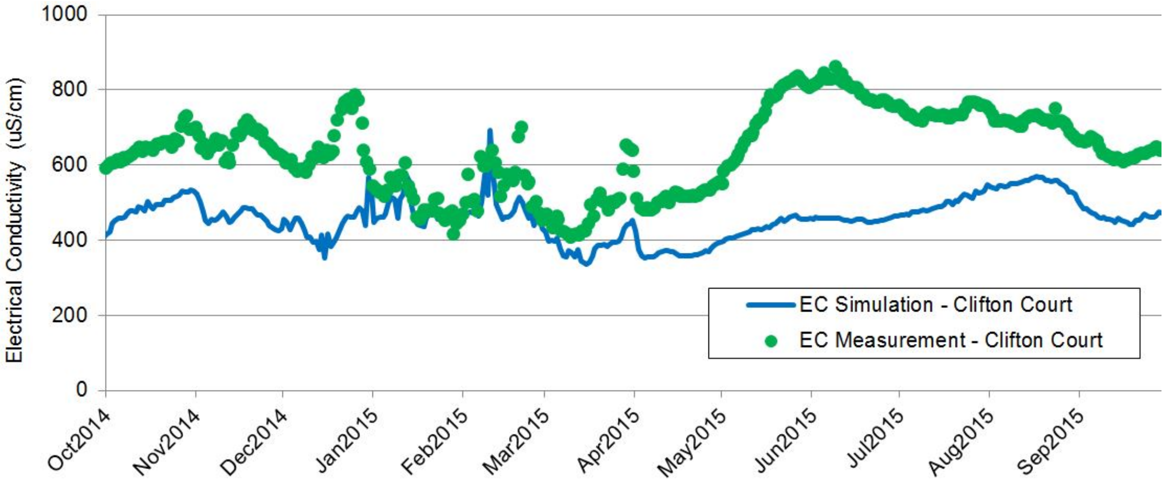


Figure 5. Figure 6-9 from BBID-384: Modeled and measured EC at Antioch (a) and at Clifton Court Forebay (b)

The conclusion that Dr. Paulsen draws from this chart is: "Even though peak measured EC values are greater than peak modeled EC in WY 2015, the model captures the overall patterns of EC at this location in WY 2015 reasonably well." (BBID-384, page 90). It appears that "reasonably well" is not a very rigorous standard. One can see that the model calculated EC is approximately 50 percent lower than the measured EC at Clifton Court starting in May (about 400 uS/cm calculated versus 600 uS/cm actual), and approximately 80 percent lower in June (about 460 uS/cm calculated versus 820 uS/cm actual). It is inappropriate to rely upon results from a model if the time period in question is off by almost a factor of two.

DWR does monthly volumetric fingerprinting, and posts the results on it's website at: http://www.water.ca.gov/waterquality/drinkingwater/public_docs/Archive%20Delta%20Fingerprints/. Figure 6 shows the model run that includes both modeled fingerprint and actual data through May 30, 2015. This figure shows the same problem that Dr. Paulsen had with the May through June time period: EC is underestimated. It is noteworthy that the time period for the underestimation in both the DWR fingerprint, and in Dr. Paulsen's model runs, coincides with the appearance of the Martinez water fingerprint source. This is the source that is the major source of salinity in the Delta. This was the last fingerprint model run posted by DWR because the modeling group that produces the fingerprints is currently working to improve the models accuracy. Exhibit WR-248 is a true and correct copy of an email I received from Mark Bettencourt on December 16, 2015. Mr. Bettencourt also confirmed that the improvements are based on overall performance, and are not related to the False River drought barrier that was installed in the delta in May 2015.

Both Dr. Paulsen's and DWR's results show that the DSM2 model is having difficulty "seeing" the arrival of one of the most important salinity source, commencing in May, just after the SWP and CVP started releasing additional water (in excess of full natural flow), for the purpose, in part, of controlling salinity in the Delta.

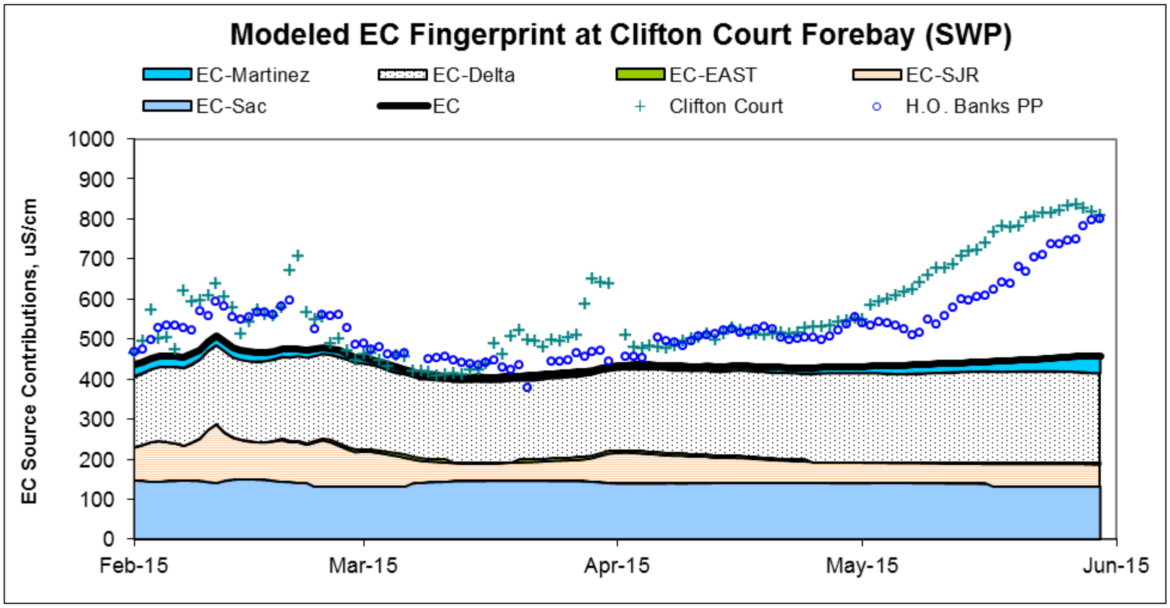


Figure 6. May 2015 Volumetric fingerprinting at Clifton Court Forebay, modeled by DWR (Archived volumetric fingerprinting are available at: http://www.water.ca.gov/waterquality/drinkingwater/public_docs/Archive%20Delta%20Fingerprints/

Dr. Paulsen's WY2015 fingerprint analysis speculates as to what may have been different in the absence of SWP and CVP storage in WY 2015; specifically highlighting that there would have been more water freshening the Delta, particularly in December and February. Dr. Paulsen goes on to discount the importance of the higher than full natural flow release in May and June by saying that these flows contributed little to the observed Sacramento River sources in the fingerprint analysis. This misses the point. Increased April, May and June flows provided the buffer of water, the salinity barrier, that keeps salt water out of the interior Delta. The speculative effects of reduced early high flows are also incorrectly interpreted.

Figure 7 shows the same info as presented by Dr. Paulsen in BBID-384 (figure 4-8 on page 43): EC at Martinez, but extends the time period to also show December 2014 (based on CDEC data, WR-246), and also adds net daily Delta outflow on the other axis. This allows one to see the effect of high Delta outflow on salinity in western Suisun Bay. Delta outflows in December were just under two million acre-feet (1,971 taf). By way of comparison the eight-river index FNF for December 2014 was 2.9 million acre-feet. EC at Martinez quickly goes down in response to these high flows. But even under these high flow conditions, with a great freshening of Suisun Bay, EC quickly increases from a low of 2,053 on 12/25/14 to over 24,192 us/cm on 1/20/15—an increase of 22,000 uS/cm in less than a month when low flows resume. An additional 900 taf (the increase if the full natural flow had arrived in the Delta) would not have substantially changed the flow/EC response. February 2015 Delta outflow was 880 taf. February full natural flow, per the eight-river index was 2,200 taf, which is similar to actual December

Delta outflow. A similar rebound to higher EC occurred one month later, in March (to 20,057 on March 10, 2015); and would also have occurred even under full natural flow conditions after the February flow event, just as it did in January. Suisun Bay is not a useful source of water except during sustained high flow events which did not occur in 2015 after February, and would not have occurred even under a no-CVP and SWP scenario in 2015.

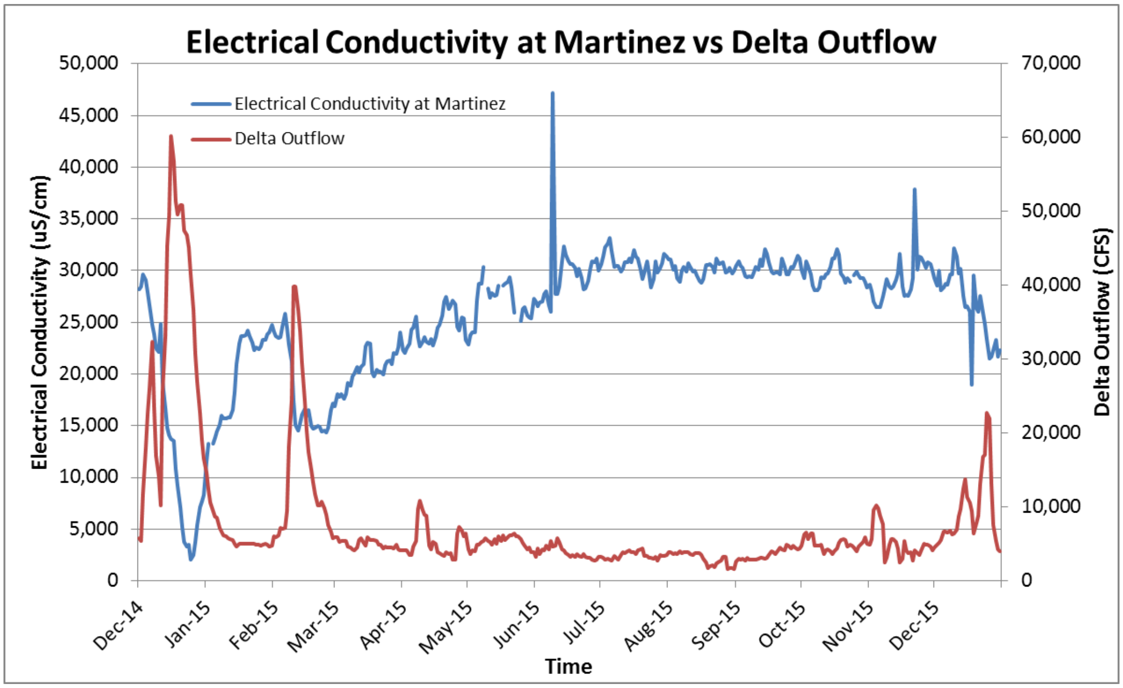


Figure 7. Delta Outflow and Martinez Electrical Conductivity (CDEC data, WR-246))

Figure 8 is a copy of the volumetric fingerprint at the BBID intake for 1931 shown with Sacramento River inflow separated according to months (Dr. Paulsen's Figure 6-7(b), BBID-384), with lines added at each ten percent volume to make it easier to draw some conclusions. Figure 9 is the same for the WSID intake (from Dr. Paulsen's Figure 6-8(b), BBID-384).

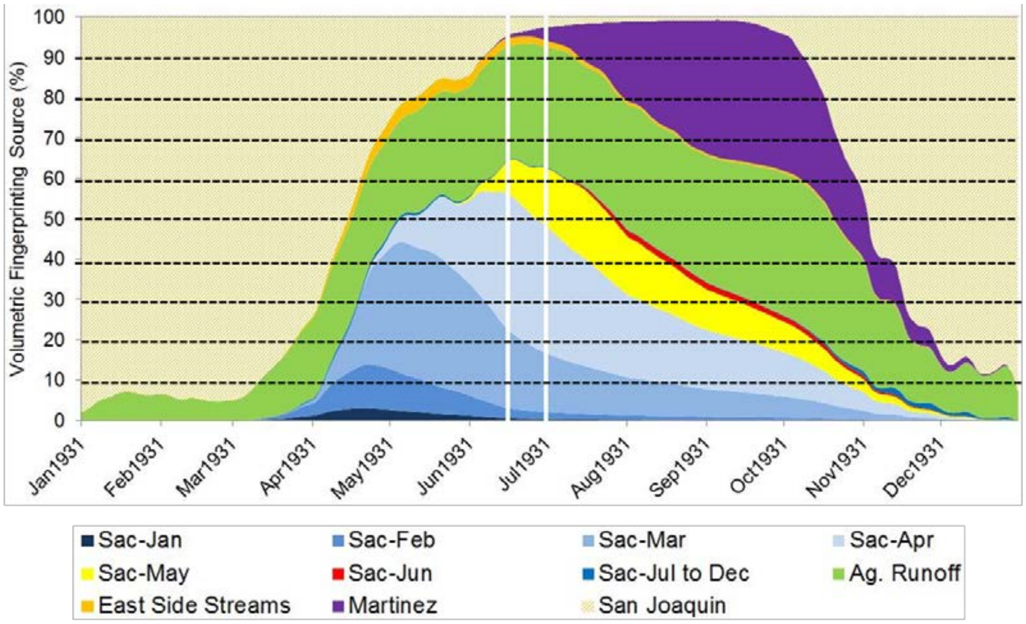


Figure 6-7(b). Volumetric fingerprint at the BBID intake for 1931 shown with Sacramento River inflow separated according to month

Figure 8. Source fingerprinting from BBID-384: Figure 6-7(b). Volumetric fingerprint at the BBID intake for 1931 shown with Sacramento River inflow separated according to month

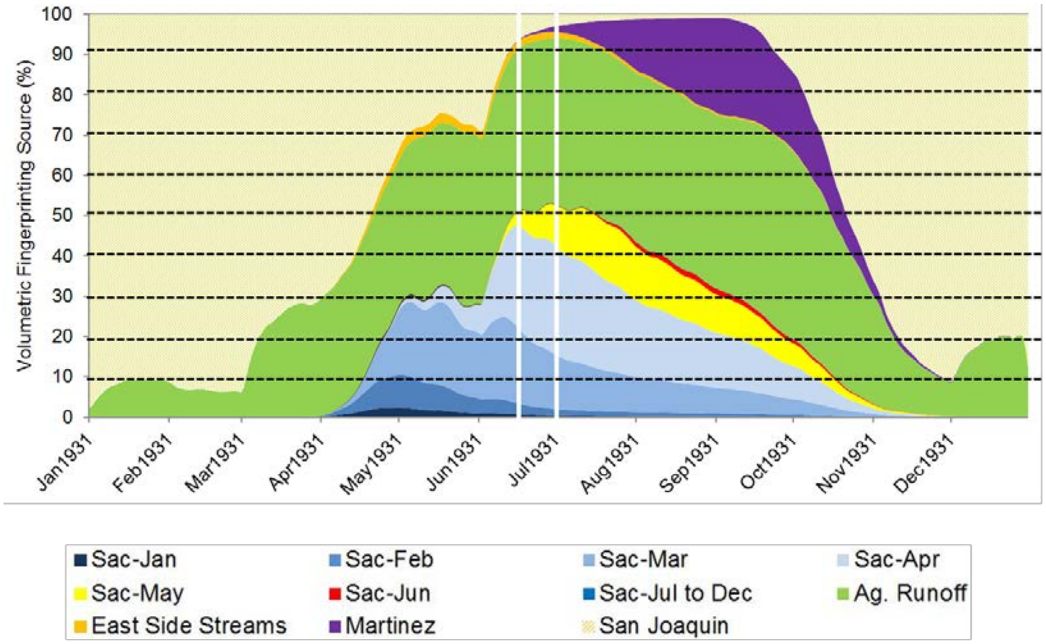


Figure 6-8(b) Volumetric fingerprint at the WSID intake for 1931 shown with Sacramento River inflow separated according to month.

Figure 9. Source fingerprinting from BBID-384: Figure 6-8(b). Volumetric fingerprint at the WSID intake for 1931 shown with Sacramento River inflow separated according to month

The volumetric fingerprint plots for WSID and BBID intakes in 1931 (from BBID 384) show:

- Sacramento River water from March and April account for about 50 percent of the water at the BBID intake and 40 percent of the WSID intake in June
- Significant volumes of Martinez water are part of the available water at WSID's and BBID's intakes starting in July, with what appears to be 15 to 20 percent by August, and 25 to over 30 percent by September.

Based on the boundary conditions used in the DSM2 runs, this means that 15 to 30 percent of the water at WSID and BBID intakes had a source water quality of 20,000 uS/cm (average of the Martinez EC values used by Dr. Paulsen in the DSM2 run). The contribution from Martinez alone would therefore account for a combined salinity of 3,000 us/cm in August and 6,000 us/cm in September, based only on the salt in the Martinez water. The additional salts from other sources, though small, would only increase the salinity.

As shown above, March through July flows were much lower in 2015 than in 1931 so conditions would have been this bad earlier in the year. As shown above the April through July flows were about 750,000 acre-feet less in 2015 than in 1931, based on the combined Sacramento and San Joaquin Valley unimpaired flows. Based on the total April through July unimpaired flow of 3.3 million AF, 750,000 af represents about a one month difference, thus it is reasonable to expect poor conditions to have commenced approximately one month earlier, in June. The eight-river index data suggests even poorer conditions. Eight-river index March, April, and May flows were 42, 61, and 43 percent lower, respectively, in WY 2015 than in WY 1931. The combined March through June eight-river index flows in 1931 were 4,157 taf, compared to 2,987 taf in 2015--39 percent lower.

Figure 10 shows the source fingerprints for water at Old River at Highway 4, Clifton Court, and WSID intake for water year 2015, showing the month when Sacramento River water entered the Delta. Figure 10 combines the information from figures 6-10(b), 6-11(b), and 6-12(b) (from BBID-384), and also adds reference lines for each ten percent of volume.

The source fingerprint plots in BBID-384 for 2015 show:

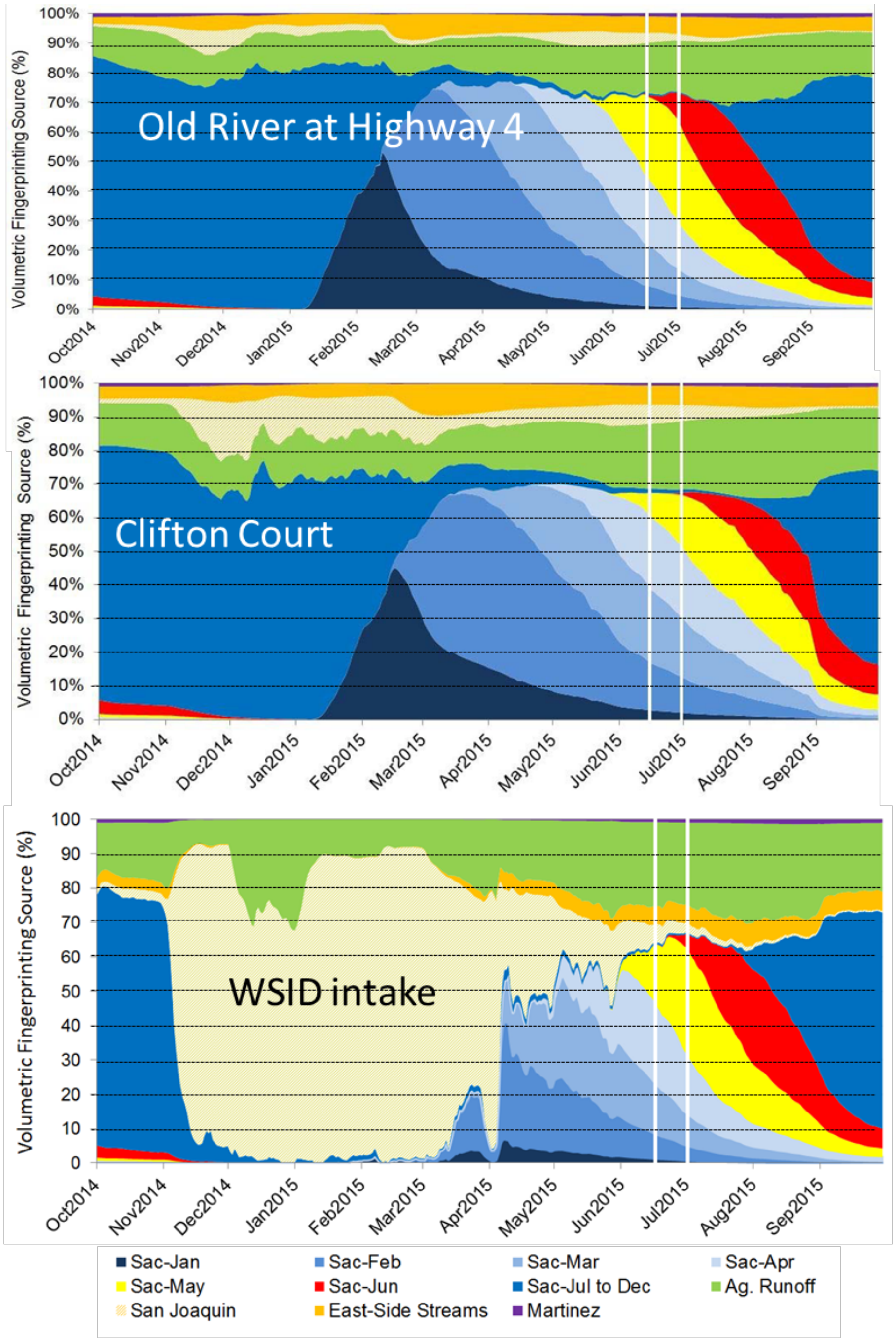
- Results at Old River at Highway 4 and Clifton Court are similar, but are significantly different from results at the WSID intake
- There is virtually no December 2014 Sacramento River water source fingerprint at WSID between in January or later(or Clifton Court),
- Less than ten percent of the water at Old River at Highway 4 and at Clifton Court had the December or earlier fingerprint by mid-March
- Never more than about five percent of the water at WSID was from February Sacramento River flows
- February 2015 Sacramento River water source accounts for about 10 percent of the water at WSID in mid June

- March 2015 Sacramento River water source accounts for about 10 to 15 percent of the water at WSID in mid June
- April and May 2015 Sacramento River water source accounts for about 40 to 45 percent of the water at WSID in mid June

The different results between Clifton Court and WSID intake occur because of the effects of SWP operations. The SWP pump relatively large quantities of water all the time compared to gross channel depletions, so when depletions are low in January, February and March, for example, CVP and SWP pumping is much greater. Per table 11, the sum of January through March pumping was 769 taf, compared with Delta gross channel depletions of 205 taf. These depletions are also spread over the entire Delta, with likely about a third in the southern Delta. This pumping has the effect of pulling more Sacramento River water into the southern Delta than if there were no pumping. The enormous difference in the magnitude and duration of the January Sacramento River volumetric fingerprint highlight this effect.

In the absence of the SWP and CVP pumping in the southern Delta these volumes of water would have gone out to Suisun Bay and mixed with sea water. Even at Clifton Court, the source fingerprint shows that the effect of high flows several months earlier has little effect on a current condition. These charts show the dissipation of the effect of a peak flow about three to four months after the peak. Conversely, the most important time period that affects water quality in the moment, are the two months prior. In WY 2015, this happens to be the timeframe during which natural flows were augmented with storage releases. Actual flows, which included releases from storage, at the four stations comprising the Sac 4-river index were 416 taf higher than full natural flows from April 1 to June 16 (based on daily data in WR-72). If one considers the depletions of full natural flow attributable to other senior upstream demand (senior to BBID and WSID), the differential is far greater (see Rebuttal Testimony of Brian Coats, Exhibit WR-210).

Absent this flow augmentation, combined with this time period of increasing gross channel depletions in May and June in the Delta, the April, May, and June water source of Sacramento River water under the current condition in 2015, would have been replaced by water from Suisun Bay. As demonstrated above, it takes a relatively small quantity of Martinez quality water to make the water supply unusable. Just a 20 percent fraction would result in EC of more than 4,000 us/cm (based on Martinez EC of 20,000 us/cm). As the April and May 2015 Sacramento River water source accounts for about 40 to 45 percent of the water at WSID's intake in June, the salinity would have been far higher at the intakes of BBID and WSID if the storage releases were replaced by Martinez quality water. The effect is not necessarily proportional because the flow augmentations in April, May and June create a salinity barrier that prevents the intrusion of, and mixing with, water from the sea.



Source fingerprints for water at Old River at Highway 4, Clifton Court, and WSID intake for water year 2015, showing the month when Sacramento River water entered the Delta (from BBID 384)

Figure 10. Source fingerprints for water at Old River at Highway 4, Clifton Court, and WSID intake for water year 2015, showing the month when Sacramento River water entered the Delta (from BBID-384)

My assumptions and determinations regarding residence time, and "what-if" outcomes based on a different set of conditions other than observed are, in the end, nearly as speculative as those advanced by Dr. Paulsen. These assumptions and determinations are also, in the end, wholly unnecessary. The DSM2 model, used appropriately, can provide a better answer about the availability of usable quality water in the Delta. The ability of DSM2 to correctly model extreme low flow conditions, apparent in Dr. Paulsen's and DWR's modeling of 2015, will need to be resolved. This statement should not, however, be taken to mean that the model is useless. As is frequently said, all models are wrong, some are useful. Based on the model runs I review, I observe that DSM2 generally does a good job modeling volumetric fingerprints and salinity, but as applied to 2015, the results I have seen suggest that it underestimates salinity during low flow, and high salinity conditions.

The most useful model run that would inform the matter of water availability was not submitted into evidence in this matter by either Mr. Burke or by Dr. Paulsen. Just such a useful model run was, however, previously analyzed and submitted by Mr. Burke as part of his testimony for the California Water Curtailment Cases (JCCP 4838). Mr. Burke's evidence in that matter was used to support the conclusion that water is always available in the Delta. This is a conclusion with which I agree, and for which there is overwhelming evidence. It is also a matter of common sense because this conclusion can be drawn simply from the fact that areas below sea level will always have a water supply—absent any physical barrier, the ocean will rush in and fill the void. The important question, however, as discussed in my July 2015 Declaration for the WSID TRO proceedings, is whether or not the water available would be usable for any purpose.

Following are conclusions in my July 3, 2015 declaration (Exhibit WR-220); these conclusions still apply:

- Although there is water present at all times at WSID's point of Diversion in the southern Delta, in the absence of releases of water from storage upstream, that water would be of a quality unsuitable for agriculture in the month of June, and continuing into July, August, and September in both a critically dry year (WY 1977) or average year (WY 1979) under no-CVP or SWP scenarios analyzed by Mr. Burke in his July 2015 declaration (Exhibit WR-221).
- The salinity at WSID's point of diversion would be high enough to be not just unsuitable in the short term, but if actually applied to crops, is high enough to have long-term negative effects on soil salinity and future crops. Unless applied in amounts far in excess of what are considered reasonable agronomic rates to provide adequate leaching of salts from the root zone, water with salinity in excess of 15 dS/cm would result in residual salinity of water in soils that would affect crop yields in subsequent years.
- The high salinities that would result in the vicinity WSID's points of diversion in the southern Delta, absent the release of stored water, as modeled by Mr. Burke in his July 2015 declaration, would also be unsuitable as a source of drinking water. The secondary Maximum Contaminant Level (MCL) for salinity is 900, which is roughly equivalent to an electrical conductivity of 1.4 dS/cm.

Following are my additional conclusions based on my assessment of unimpaired flows in WY2015 and the volumetric fingerprint analyses done by Dr. Paulsen, and that build on conclusions in my July 2015 declaration:

1. Although there is water present at all times at BBID's and WSID's points of Diversion in the southern Delta, in the absence of releases of water from storage upstream in April, May, and June, and in the absence of SWP and CVP diversions in southern Delta in January through June, water would be of a quality unsuitable for agriculture in the month of June, and continuing into July, August, and September in 2015.
2. Conclusion 1 does not however, preclude the argument that prior month, and non-SWP and CVP conditions should be considered in other less dry years to determine water availability based on an assessment of, and considering, antecedent conditions.
3. The specific parameters used to inform the hypothetical set of conditions under which an alternative determination of water availability could be made must be determined. One important example is threshold value of salinity at which a determination of no availability, even with consideration of antecedent conditions, could be determined. There will likely be competing and conflicting arguments as to the determination of water quality thresholds, including:
    a) The quality should be based on the quality of water that a water right holder senior to the CVP and SWP is "willing to, and wishes to divert". This quantity could very well be a relatively high salinity that is needed to simply keep a permanent crop alive for the current season;
    b) The quality should be based on a quality of water that the CVP and SWP must maintain to provide a useful supply under their water right.

    The salinity to support argument 3a is likely far higher than the salinity needed to support argument 3b. So, what to do? This is likely a question for future policy deliberations, and does not need to be resolved in these enforcement proceedings, which address specific conditions in an extreme water year.
4. When doing similar year analysis or modeling, other factors must be considered to determine what water quality may have been in the absence of the CVP and SWP, including disclosure and analysis of other differences between years, such as:
    a) changes in channel geometry in the delta and upstream of the Delta, and changes in natural storage in upstream water sheds;
    b) if it is assumed there is no upstream storage by CVP and SWP, it must also be assumed that there are no SWP and CVP exports that increase the draw of Sacramento River water into the southern Delta; and
    c) development and increased consumptive use of other senior water rights (more senior than BBID and WSID) compared to a historic condition.