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On behalf of South Delta Water Agency, Central Delta Water Agency, Lafayette Ranch, Heritage Lands, Mark Bachetti Farms and Rudy Mussi Investments L.P.

STATE OF CALIFORNIA

STATE WATER RESOURCES CONTROL BOARD

Hearing in the Matter of California Department of Water Resources and United States Department of the Interior, Bureau of Reclamation Request for a Change in Point of Diversion for California Water Fix	**REBUTTAL TESTIMONY OF THOMAS K. BURKE, PART 2**

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SDWA-323-revised

I, Thomas Burke, submit this written testimony at the request of Protestants South Delta Agency, Central Delta Water Agency, Lafayette Ranch, Heritage Land Company, Mark Bachetti Farms and Rudy Mussi Investments L.P., the ("South Delta Parties/Protestants").

I. Background and Qualifications

I am a hydrologist and water resources engineer with over 35 years of experience in surface water and groundwater hydrologic modeling. Prior to starting Hydrologic Systems, I held the position of Senior Associate with PWA, Western Regional Director of Water Resources for EA Engineering Science and Technology, and Hydraulic Engineer with the US Army Corps of Engineers. My experience ranges from development of two and three-dimensional river and reservoir flow and circulation models to local and regional groundwater and transport models for basin-wide hydrologic analyses. My experience also includes the analysis of one and two-dimensional flow in river and wetland systems.

I hold a Master of Science in Civil Engineering from Colorado State University, Fort Collins (1992) and hold a Bachelor of Science in Civil Engineering from The University of Florida, Gainesville (1980). My Statement of Qualifications is marked as SDWA-47.

II. Overview of Testimony

In Part 2 of the California WaterFix Petitioners presented a new operations (CWF H3+) as their preferred scenario/adopted Project. In conjunction with the submittal of their Part 2 testimony Petitioners released Delta Simulation Model (DSM2) modeling files for the CWF H3+ scenario. Petitioners provided conclusions and opinions concerning the potential impacts of the proposed project, and the CWF H3+ scenario in particular. In significant aspects, which I will discuss below, Petitioners' testimony misrepresents the actual impacts of the project, including the CWF H3+ scenario. It should be understood that Protestants did not have access to the CWF H3+ modeling files until the Part 2 proceedings began. Thus, a significant part of my rebuttal testimony is again, focused on salinity effects in the South and Central Delta resulting from the CWF H3+ scenario.

SDWA-323-revised

The foundation of the Petitioners analysis of the CWF, ("Project") and its potential impacts is based on the results of the CALSIM II and DSM2 modeling of each of the different scenarios that are part of their water rights change petition. The results of that modeling work were presented in Part 1 and Part 2 of this hearing. Although the scenarios have been changing through the course of this hearing, the models used to evaluate those scenarios have not. To accurately predict the conditions resulting from the different scenarios, the models must be able to accurately reflect the change in hydrodynamics and water quality with respect to the existing condition. An evaluation of the existing DSM2 model shows that it does not accurately reflect the existing channel conditions in the South Delta. Without being able to accurately model the existing hydrodynamic conditions in the south Delta, Petitioners analysis of any change to that existing condition will be incorrect. A No Action Alternative ("NAA") based on significantly inaccurate channel conditions in the south Delta results in a significantly inaccurate effects analysis.

As part of DWR's testimony presented in Part 2 of this hearing, Mr. Eric Reyes, provided several opinions with regard to the analytical framework that was used to evaluate the hydrologic and water quality impacts from the Project. A summary of those opinions are listed below:

i. CWF H3+ complies with Water Rights Decision of D1641
ii. CWF H3+ complies with the 2008/09 BO's requirements for Old and Middle River flows, and that Old and Middle Rivers remained more positive and less negative than the NAA
iii. The evaluation of time steps shorter than annual monthly averages is inappropriate for the CWF but the models are appropriate for comparing scenarios.

As part of DWR's testimony presented in Part 2 of this hearing, Ms. Tara Smith provided several opinions with regarding averaged water quality and stage as they relate to water quality standards. Those opinions are summarized below:

i. CWF H3+ is in compliance with D-1641 water quality objectives

ii. There is no significant increase in salinity levels between CWF H3+, BA H3+, and the NAA.

iii. There is no significant impact on Water levels between CWF H3+, BA H3+, and the NAA.

iv. Citing Dr. Nader-Tehrani's testimony in Part 1, exceedances from the Project scenarios compared to the NAA are mostly a result in the difference in modeling assumptions for each scenario.

As part of DWR's testimony presented during Phase 2 of the hearing, Dr. Bryan provided an opinion that the Sacramento River is in thermal equilibrium with the air temperature and therefore a reduction in cold water flows entering the Delta will not impact water temperatures therein. Dr. Bryan based his opinion on theoretical models and does not appear to have considered site specific data. The Part 2 rebuttal testimony herein addresses the opinions of Mr. Reyes, Ms. Smith, and Dr. Bryan as summarized above.

III. The Project Comprises More than the CWF H3+ Scenario

As a foundation to this rebuttal testimony, it is crucial to understand that there are important impacts that result directly from the implementation not only of the "Preferred Scenario/Adopted Project", as described in the CWF H3+ scenario, but in the range of potential operations that were defined by the B1 and B2 scenarios. The impacts from these two scenarios, which represent the expected boundary limits of the proposed Project operations, were described in Part 1 of this hearing.

Additionally, the CWF H3+ scenario is not the "Project". The CWF H3+ scenario is the preferred set of operations that the Petitioners will try to meet, but the "Project" is the set of all scenarios and operations for which they are requesting a permit. Therefore, to evaluate the "Project", the impacts from the CWF H3+ must be viewed together with the range of impacts from scenarios B1 through B2. ~~Moreover, pursuant to the BiOPS and the ITP, adaptive management is required as part of the Project. Consequently, despite the implication of Petitioners Part 2 testimony, Project operations necessarily will not mirror those reflected~~

SDWA-323-revised

~~by the CWF H3+ scenario~~. Thus, it is important to treat the B1 and B2 scenarios as the outer limits of the Project operations as set forth in the Change Petition ("Petition").

IV. Summary of Part 2 Rebuttal Opinions

1. The CWF H3+ scenario will have significant impacts on the salinity in the South and Central Delta.
2. The DSM2 model does not accurately reflect the existing channel geometry for significant portions of the South Delta channels. The difference between the existing geometry and the geometry in the DSM2 model is so great that the flow, stage, and movement of salts through the South Delta will be inaccurate when the model is used in a predictive or comparative mode.
3. The most recent version of the DSM2 model should be used in the CWF analysis and evaluation.
4. The existing NAA does not comply with the D-1641 requirements at the "Old River at Tracy" compliance point. With an expected increase in salinity for CWF H3+ , the inability to comply with D-1641 at this compliance point is exacerbated.
5. The Project CFW H3+ scenario results in an increase in reverse flows for Old and Middle Rivers.
6. The CWF H3+ scenario results in a significant reduction in water levels in Old and Middle Rivers. This reduction severely impacts areas of those channels that are already much shallower than predicted in the DSM2 model.
7. The DSM2 hydrodynamic model can be appropriately used to evaluate flow, stage, and water quality data on a time step as short as 15-minutes. Time steps shorter than 15 minutes were investigated by DWR, but they found that the 15-minute time step provided the best balance between accuracy and computational efficiency.

8. There is evidence to indicate that the Sacramento River may not be in temperature equilibrium with the air temperature. This could impact the Delta downstream of the NDD's.

V. Discussion of Testimony

Salinity Analysis

The CWF H3+ results in an increase in salinity across most of the South and Central Delta. The increase in salinity occurs for extended periods of time in both wet and dry water year types. As demonstrated in my Part 1 testimony, there is also an increase in salinity under the B1 and B2 scenarios. To determine the extent and duration of these increases, the output from the DSM2 hydrodynamic and water quality model was evaluated. Those results were presented as SDWA-76 and SDWA-78. In preparing my Part 2 rebuttal testimony I evaluated the impacts from the proposed CWF H3+ scenario using Petitioners unmodified DSM2 and CALSIM models as posted on the Hearing FTP site.

Changes to salinity and stage from the CWF H3+ scenario were evaluated by comparing the salinity in the Delta at specific locations to the salinity and stage at those same locations in the NAA. The models for the CWF H3+ and NAA scenarios were run through the 1921 - 2003 water year time frame to determine how the scenario would affect the Delta through the greatest diversity of water year types. The actual comparison between the two model scenarios was between the 1923 through 2003 water years. This allowed both models to go through a process called "spinning up", which is the time it takes for the models to become fully responsive to the inflows to the Delta as well as the tidal boundary condition.

Figures 1 and 2 below are plan view maps showing the location of the 10 sites in the Central and South Delta where I evaluated the change in salinity from the NAA to CWF H3+ scenario. The locations were selected to 1) analyze areas where there are known salinity problems, and 2) to represent a range of locations throughout the southern Delta. Areas of known salinity problems were selected because an increase in salinity at these areas will exacerbate an existing problem. Table 1 provides a list of the different analysis points.

The DSM 2 model calculates the flow, stage, and water quality throughout the Delta on a 15-minute time-step. This small time-step is necessary to allow the model to properly respond to tidal changes. The rising and falling tide is one of the major forces driving water through the Delta. Failing to account for the diurnal change of tides each day is problematic in analyzing Delta hydrodynamics. Due to the number of 15-minute time steps in the 1921-2003 period (over 3 Million), the 15-minute values were averaged to create a daily average of flow, stage, and water quality at each location. Averaging of the 15-minute data differs from data developed using a daily time step, because the daily time step does not account for how the tide changes throughout the day. The analysis that I presented in Part 1 of this hearing was based on a 15-minute time step without any daily averaging. Comparing the 15-minute time step data over a 16-year period (the time frame chosen by Petitioners) was feasible, but evaluating the 15-minute data over 80 years (the time frame used by the Petitioners in Part 2) was not practical. Comparing the daily data may not be quite as telling as the 15-minute data, but is still much more relevant than averaging over a monthly or mean monthly period, which is what the petitioners did. Averaging over long periods masks much of the variability in salinity.

SDWA-323-revised

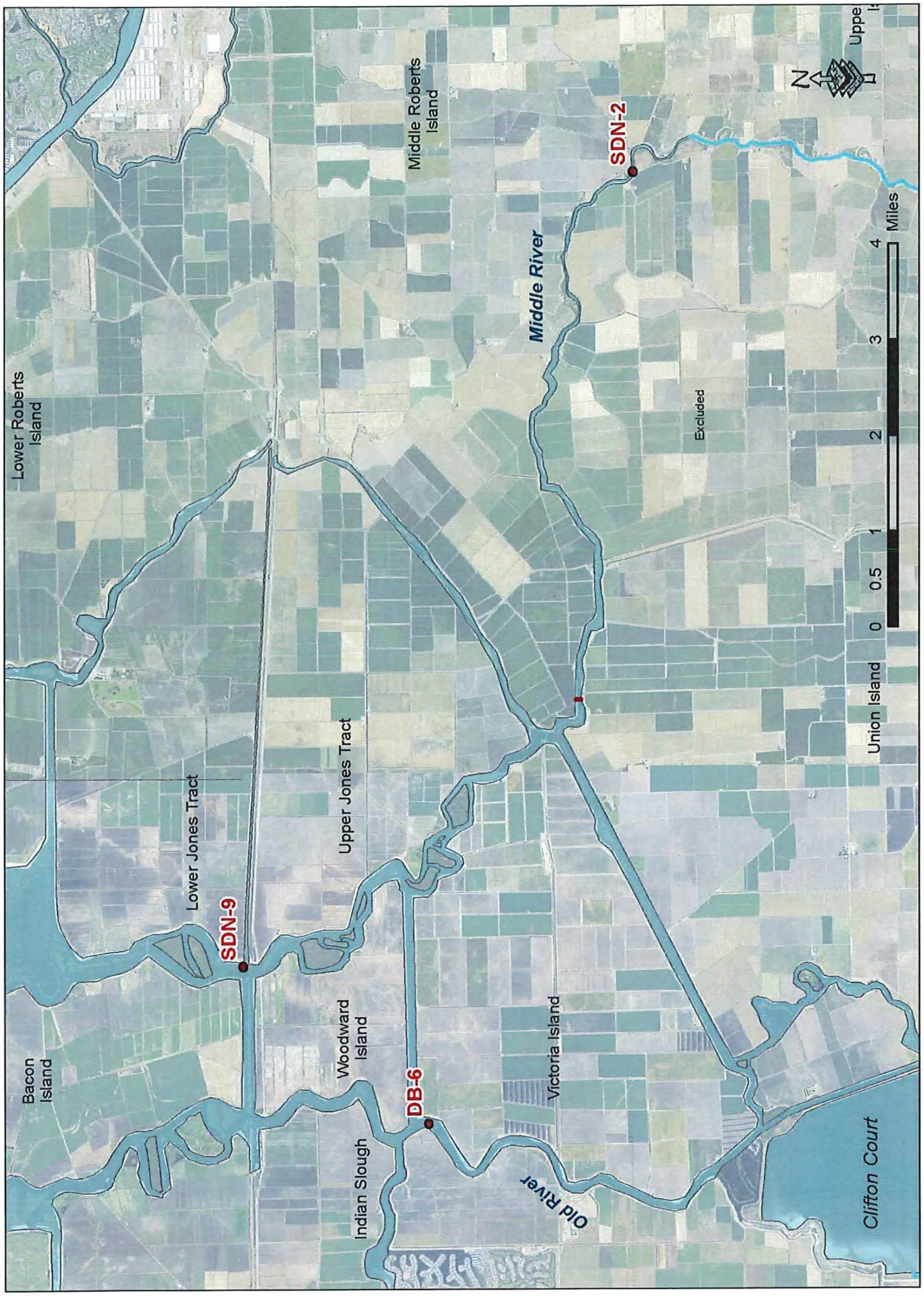

Figure 1 Location of the Central Delta Salinity Analysis Points

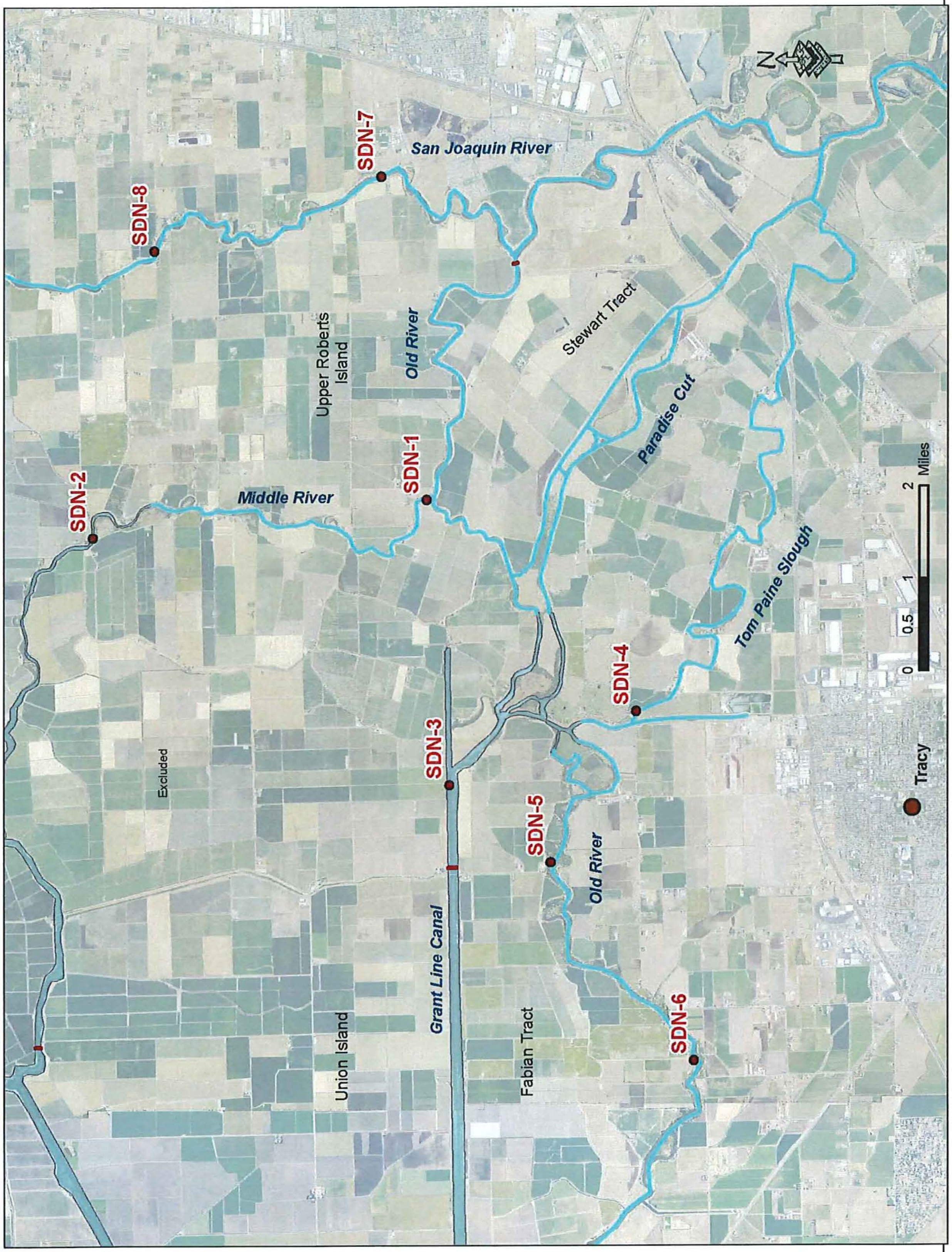

Figure 2 Location of the South Delta Salinity Analysis Points

Table 1 Salinity Analysis Points

No.	ID	Location Name	DSM2 Channel Number
1	SDN1	Old River at Tracy	71
2	SDN2	Old River 1	75
3	SDN3	Grant Line Canal	206
4	SDN4	Head of Middle River	125
5	SDN5	Middle River at Howard Road Bridge	129
6	SDN6	Middle River at P.O.	145
7	SDN7	Tom Paine Slough	194
8	SDN8	San Joaquin River 1	9
9	SDN9	San Joaquin River at Brandt Bridge	10
11	SDN10	Old River Down Stream of Indian Slough	94

Results

The difference in salinity between the CWF H3+ scenario and the NAA was calculated at each of the analysis points shown in Table 1. The difference in salinity between the CWF H3+ scenario and the NAA were plotted for several representative water year types. Figure 3 and 4 show the difference in Salinity for Sites SDN1, "Old River at Tracy" and SDN4, "Middle River at Head". The plots for each of the remaining sites are provided in Appendix A. A positive difference on the plot represents a condition where the salinity is higher under the CWF H3+ than under the NAA. As can be seen in these two figures, there is a considerable amount of time when the salinity is greater under the CWF scenario than under the NAA. This same trend is repeated for the other locations as well.

Examination of the difference plots shows periods when the salinity has increased and decreased. Further analysis described below, shows that the periods of increase far exceed the periods where the salinity may decrease. But, even with that, a simple sum of the increases and decreases in salinity across a long period of time is not an appropriate way of looking at the impacts to plants and their soil profiles that will result from the increases of the salinity. (See testimony of Terry Prichard SDWA–92). A degradation in water quality during one period may not be offset by an improvement in water quality during another. Responses from aquatic species, crops, recreational users and other beneficial uses of the Delta are to conditions as they exist in real time, not over a long term average. An analogy would be to reduce a person's oxygen supply by ½ this month and assume that the resulting damage can be offset by a doubling of their oxygen supply next month. Decreasing the water quality, especially to a system like the Delta, that is already under extreme stress, will create additional stressors that could further imperil the beneficial and legal users of the Delta.

Petitioners have not provided any agricultural or soils experts to opine on how changes in salinity from the Project will affect agriculture.

I also evaluated the amount of time that the salinity is greater under the CWF than the NAA for each of the locations that were analyzed. The results of that analysis are provided below in Table 2. The table provides the amount of time that the CWF results in a higher salinity level than the NAA for the average daily salinity, the maximum daily salinity, and the minimum daily salinity over 80 years. As shown, the increase in the amount of time that these Central Delta and South Delta sites have elevated salinity levels due to the CWF H3+ scenario range from 76% at the Head of Middle River to 54% at Tom Paine Slough. Not only does the average daily salinity increase, but the CWF H3+ scenario results in an increase in the amount of time that the daily high, and the daily low salinity levels are elevated as well. This results in higher highs, higher lows, and higher averages salinity levels at each location. The CWF H3+ scenario results in an increase in salinity at all sites except SDN8 and SDN9, which are on the San Joaquin River.

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Table 2 Percentage of Time That The CWF H3+ Scenario Results In Greater Salinity Than The NAA

Site	Daily High Salinity Difference	Average Daily Salinity Difference	Minimum Daily Salinity Difference
SDN-1	62%	65%	66%
SDN-2	62%	61%	61%
SDN-3	70%	72%	73%
SDN-4	76%	76%	76%
SDN-5	57%	56%	54%
SDN-6	68%	68%	69%
SDN-7	54%	56%	63%
SDN-8	34%	35%	41%
SDN-9	32%	29%	30%
SDN-10	59%	60%	60%

It's important to note that these increases in salinity are not just isolated spikes due to random configurations of the two scenarios. They often represent extended durations of elevated salinity levels that can occur during all water year types. Figures 5 is an example of the change in salinity for a dry year. This plot shows the difference in salinity between the CWF H3+ and the NAA for Water Year 1987. It was considered a Dry year for the Sacramento River Basin, and a Critically Dry year for the San Joaquin River Basin. As shown in Table 2, the magnitude of increased salinity are significant both in terms of intensity and duration. These periods of increased salinity often last for several months, and can be seen in Dry, Above Normal and Wet water years. Figures 6 and 7 show the difference in salinity between the CWF H3+ and the NAA for WY 1973, which was considered an Above Normal Water Year, and 1996, which was considered a Wet Water Year.

The determination of a water years classification is made by DWR, and published in their "Water Year Hydrologic Classification Indices" web page[1]

[1] HYPERLINK "http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST"

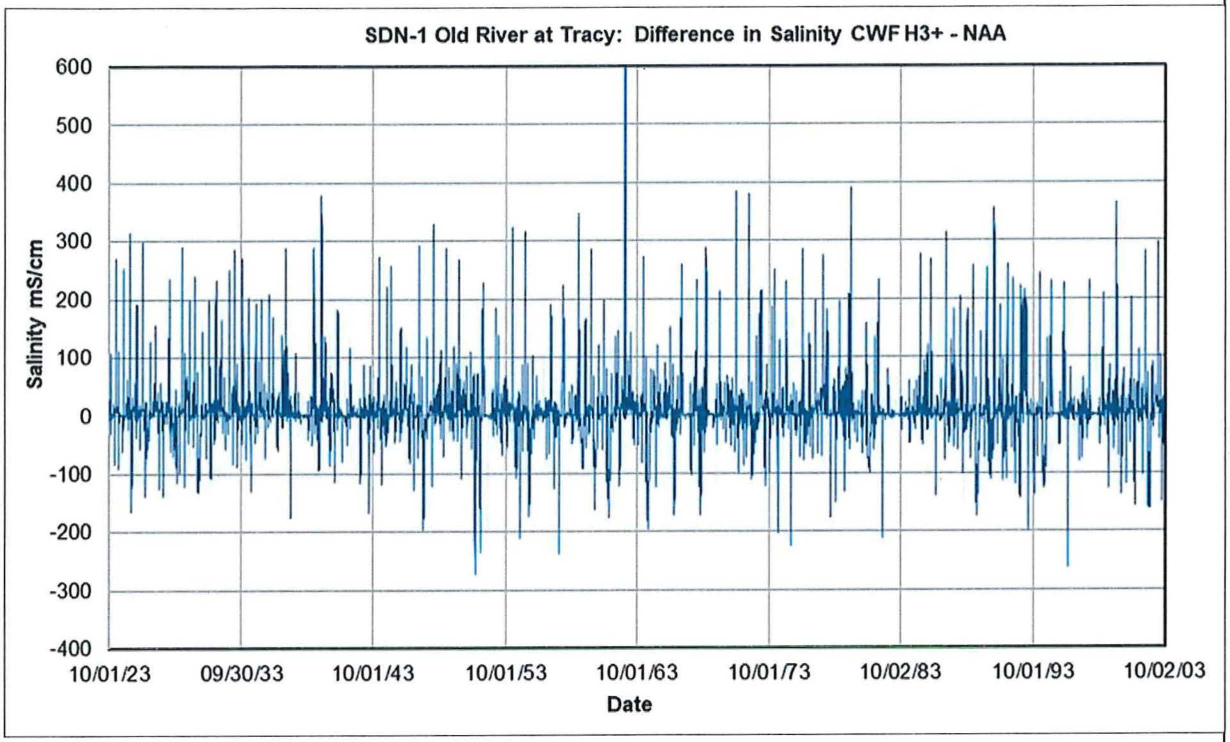

Figure 3 Salinity Difference: "Old River at Tracy"

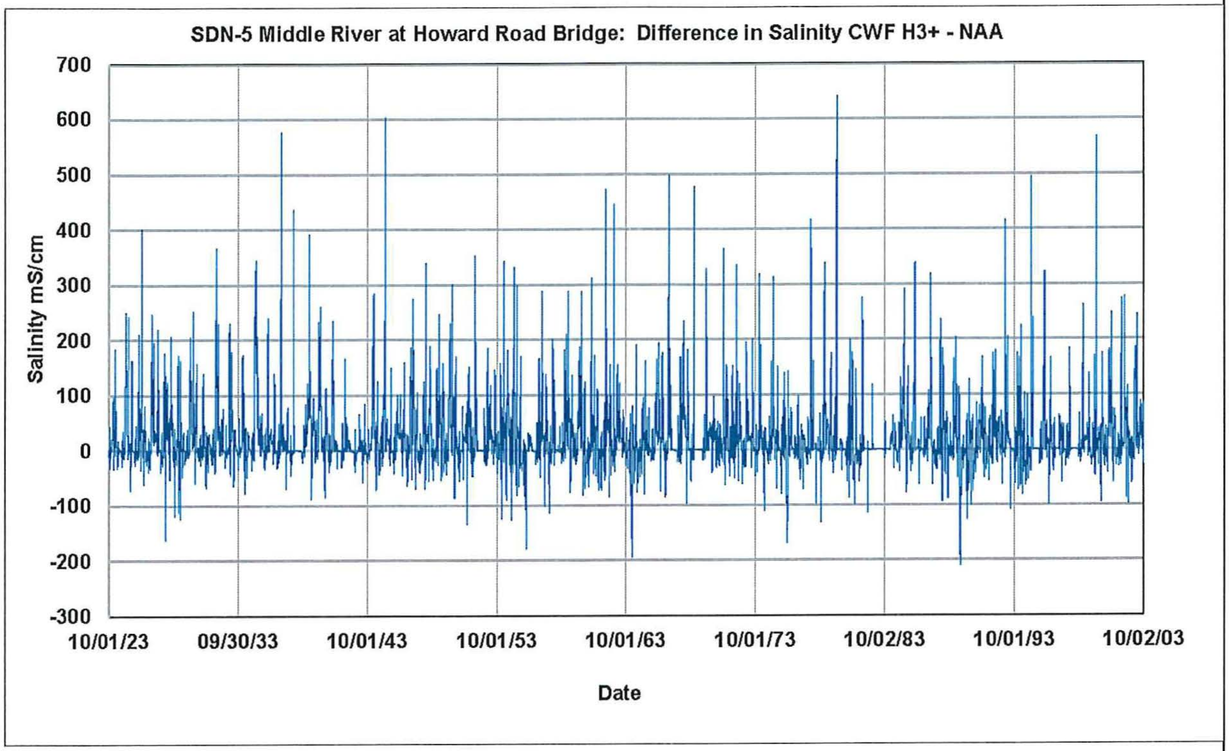

Figure 4 Salinity Difference " Middle River at Howard Road Bridge"

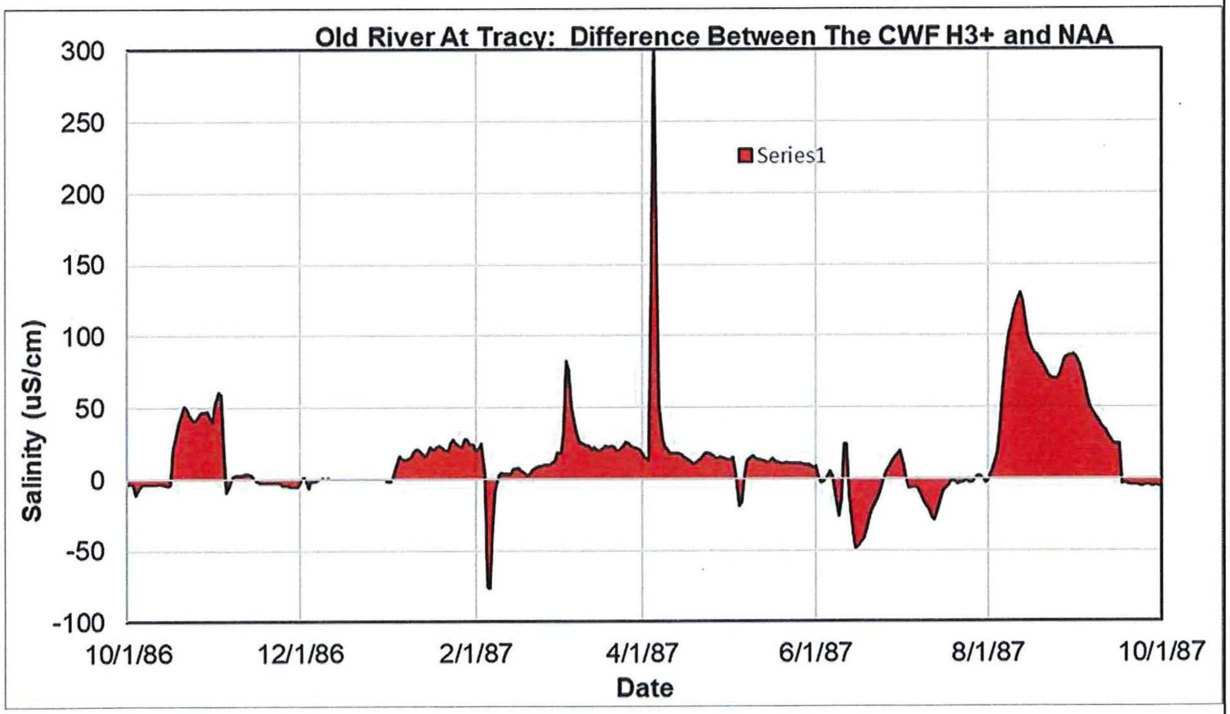

Figure 5 Difference in Salinity WY 1987 "Critically Dry Water Year"

SDWA-323-revised

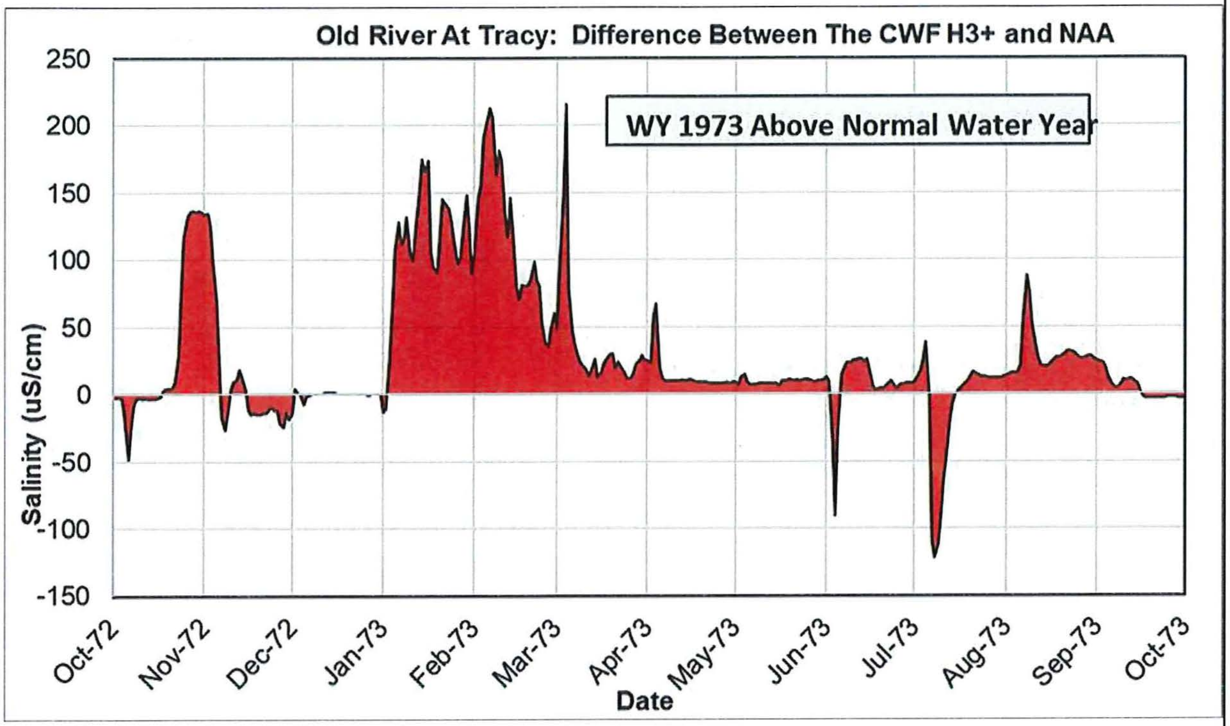

Figure 6 Salinity Difference; WY 1973, "Above Normal Water Year"

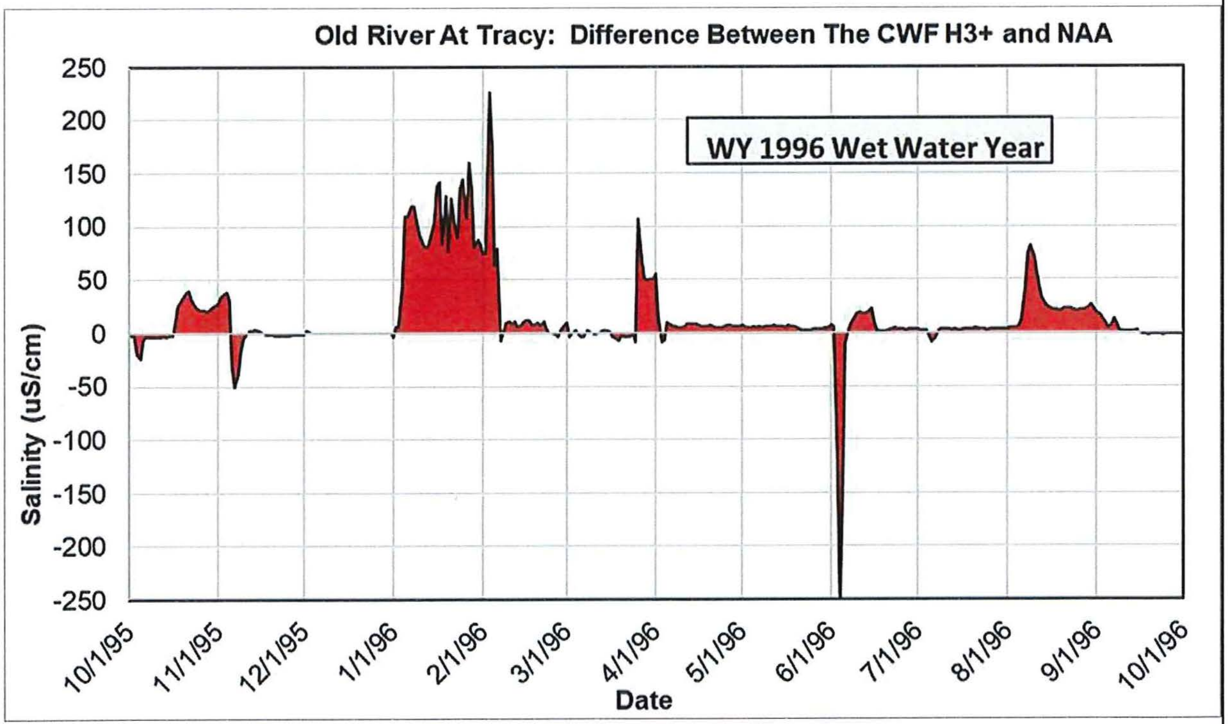

Figure 7 Salinity Difference; WY 1996, "Wet Water Year"

An analysis of the frequency and intensity of the salinity increases between the CWF H3+ scenario and the NAA was conducted. This analysis helps determine the intensity and frequency of the salinity increases resulting from the CWF H3+ scenario. This analysis was conducted on the differences between the CWF H3+ and the NAA for the mean daily salinity data, the daily low salinity data, and the daily high salinity value. The data for those three conditions are provided in Table 3.

As an example, reading from the table, you can see that for the Middle River at Post Office location, under the CWF H3+ scenario, 10% of the time there will be an increase of 123 μS/cm, and 20% of the time, there will be a salinity increase of 81 μS/cm. These are not insignificant increases. It also bears repeating that based on Mr. Prichard's testimony (SDWA-92) damages to crops from increased salinity is not mitigated by some future decrease and Petitioners have provided no expert testimony suggesting otherwise.

Table 3 Percent of Time That Salinity increase From CWF H3+ is Greater Than or Equal to The Specified Value (μS/cm)

Frequency	SDN-1	SDN-2	SDN-3	SDN-4	SDN-5	SDN-6	SDN-7	SDN-8	SDN-9	SDN-10
Percent of Time	Old River at Tracy	Old River 1	Grant Line US of Barrier	Head of Middle River	Middle River at Howard Road Bridge	Middle River at Post Office	Tom Paine Slough	San Joaquin River 1	San Joaquin River at Brandt Bridge	Old River DS of Indian Slough
Average Daily Values:										
40.0%	8	16	2	1	16	38	3	0	0	34
30.0%	12	27	4	2	28	55	6	0	0	56
20.0%	**18**	43	6	3	44	**81**	13	0	0	**92**
10.0%	**33**	80	12	4	83	**123**	29	0	0	**160**
5.0%	63	119	21	6	127	166	52	1	1	253
Max Increase	1123	1154	508	189	640	458	917	68	106	607
Max Daily Salinity Values:										
40.0%	6	15	2	1	11	37	4	0	0	34
30.0%	10	26	4	3	26	54	8	0	0	56
20.0%	15	41	7	4	46	79	15	0	0	92
10.0%	29	79	14	7	99	127	33	1	1	161
5.0%	56	120	25	10	157	168	60	2	3	255
Max Increase	1137	1161	770	480	687	448	976	60	249	691
Minimum Daily Salinity Values:										
40.0%	7	13	2	1	10	38	3	0	0	31
30.0%	10	22	3	2	19	55	5	0	0	52
20.0%	17	35	5	2	35	79	12	0	0	86
10.0%	32	64	9	3	71	119	28	0	0	153
5.0%	58	109	15	5	119	161	49	1	1	241
Max Increase	1084	1101	403	455	633	447	982	107	186	730

Channel Geometry Analysis

SDWA-323-revised

The Petitioners analysis of the proposed Project has been based, to a large extent, on the results from the DSM2 hydrodynamic model. DSM2 is the most commonly used model for evaluating and predicting in-Delta flows, quality, and stage. But, like any model no matter how computationally accurate it may or may-not be, it is only as good as the geometry that is used to represent the channels within the system. The Delta consists of an interconnected network of channels. These channels act as a unified system that responds to flow entering and leaving the system at the boundary points. Changes to any of the interconnected channels will result in a redistribution of flow to that channel and the other channels in the system.

Many issues have been reported recently concerning shallow water levels in the south Delta. The reported shallow conditions did not appear to be consistent with the results of the DSM2 model that represents the existing condition. To determine why there was this inconsistency between the model results and the actual observed conditions in the Delta, in July of 2018 a bathymetric survey was conducted of Old River and Middle River. The results from this survey were then compared to the geometry of those locations that are used in the DSM2 model. A copy of that survey data has been provided in Exhibit SDWA-326

Figures 8 is a site map showing the location of eight cross-sections that were surveyed on, Middle River. Figures 9-11 are representative plots of three of the eight cross-sections that were surveyed on Middle River. The DSM2 channel geometry for each of these locations has been plotted in red on top of the surveyed cross-section that is shown in brown. As can be seen in the figures, the DSM2 channel cross sections are significantly larger and deeper than the actual channel geometry of Middle River. The mean water line as computed in the DSM2 model is also shown in each figure. Inspection of the area below the mean water line shows that the DSM2 cross-section has a flow area that is roughly 20 times larger than it is in the actual cross-section. That is a very large difference in geometry between the DSM2 model and the actual geometry of Middle River. For location MR-7, the computed mean daily water level from the DSM2 model is at the bottom of the actual channel. The actual channel is not even within the flow area that is being used in the DSM2 model. Figures 12 and 13 are photographs of Middle River at Undine Road, near the location of MR-7. As can be seen in the photos, the water level at this location reflects the condition observed in Figures 9-11.

With the difference in channel geometry as large as indicated in these cross-sections, any estimate of flow or depth in Middle River that is based on the DSM2 modeling is fundamentally incorrect. In my opinion, the actual flow in Middle river could be as low as 5 to 20% of what the model is computing. In addition, any estimate in the change in flow, depth, or water quality, due to any project scenario, would be completely wrong. Because the Delta is a system of interconnected channels, a change in flow to one channel results in a redistribution of flow within the other channels. The error in the Middle River geometry will not only affect the modeling results for Middle River, but will initiate a cascading set of errors in flow and stage that will have a ripple effect into the adjacent channels of Old River and San Joaquin River.

In addition to the channel geometry issues in the DSM2 model, it is recommended that the most recent version of the model be used in the analysis. All of the analysis that has been presented by the Petitioners has been developed using an older version of DSM2. This version referred to as Version 8.0.6, was finalized in 2010. The most recent version, 8.1.2, was finalized in 2013. This latest version, which has been available for 5 years, would provide the Petitioners with the best available model (minus the continuing geometry problems) for evaluating the CWF scenarios. Many changes and improvements were in incorporated into this latest version. Those modeling improvements will not be reflected in the analysis that has been presented. Given the significance of what the Petitioners are proposing, not using the best available model and data is not acceptable.

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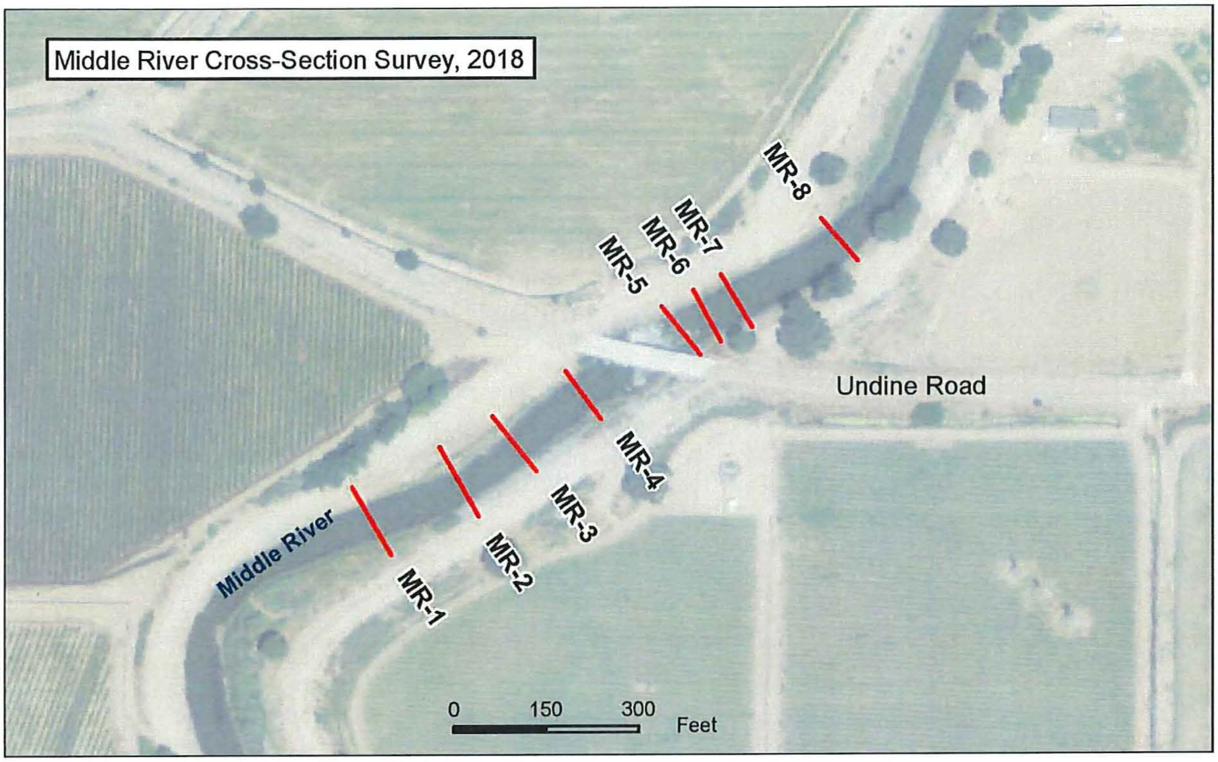

Figure 8 Location of Surveyed Cross-Sections on Middle River.

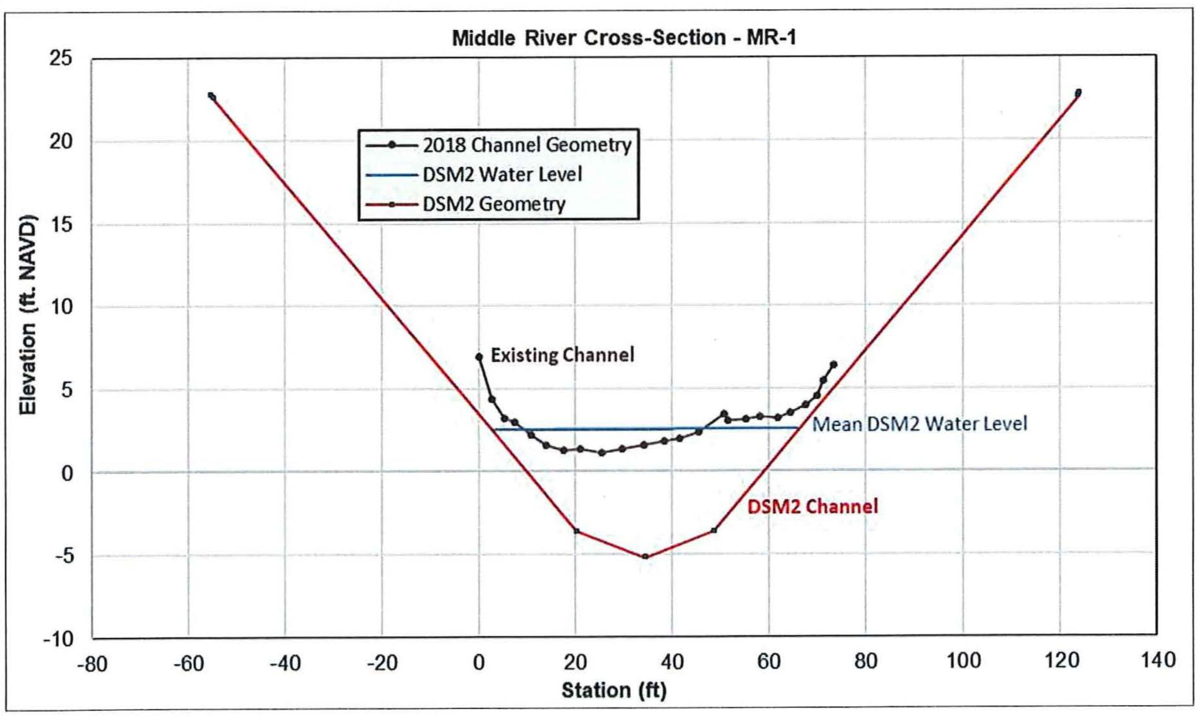

Figure 9 Comparison of DSM2 Geometry at Middle River Cross-Section MR-1

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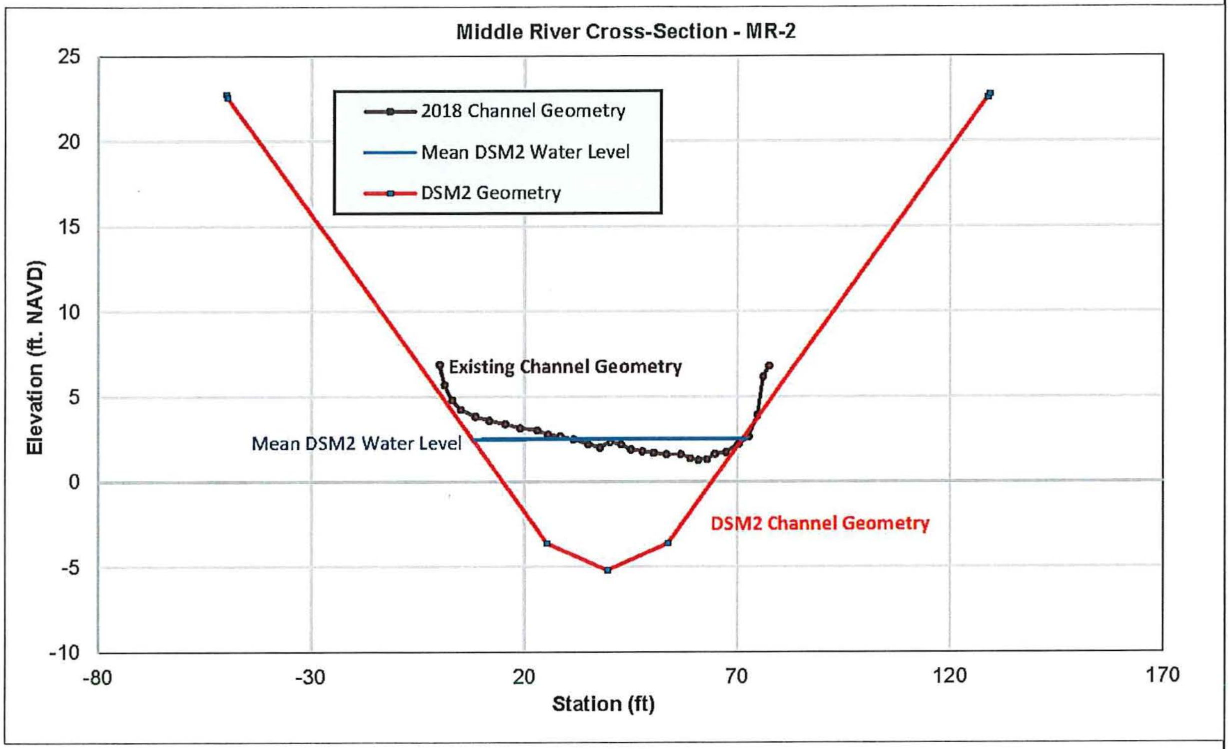

Figure 10 Comparison of DSM2 Geometry at Middle River Cross-Section MR-2

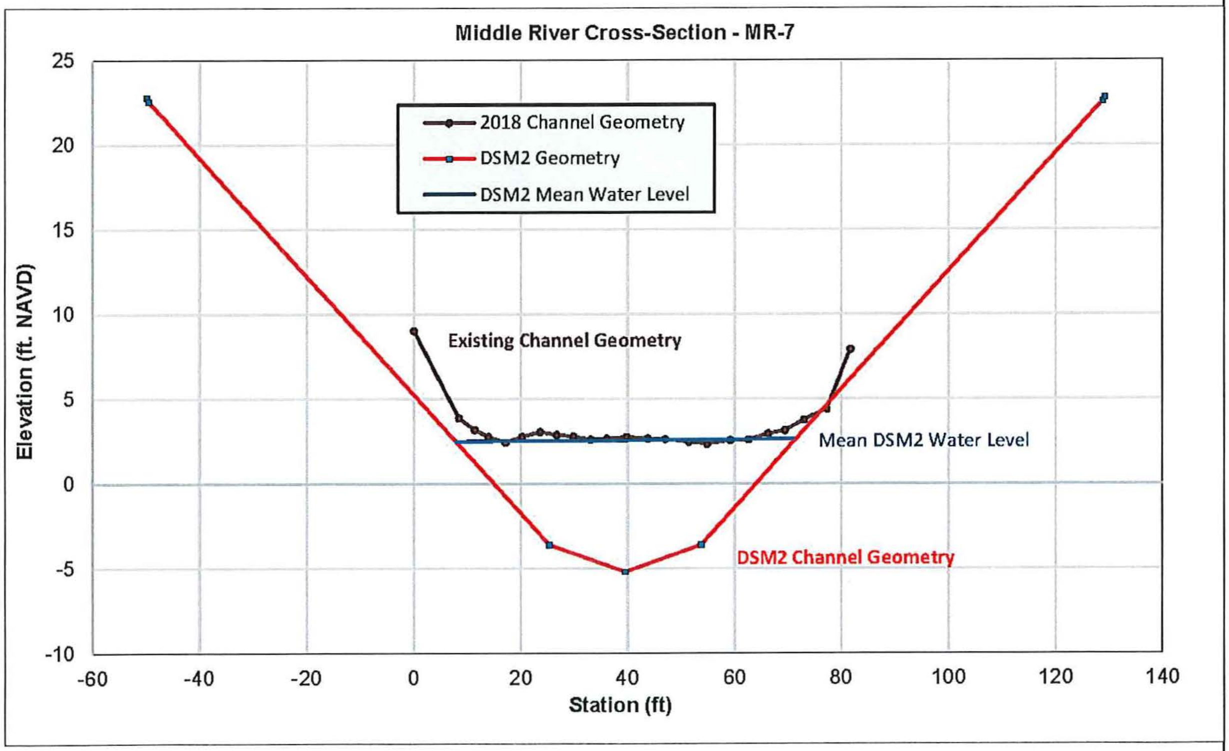

Figure 11 Comparison of DSM2 Geometry at Middle River Cross-Section MR-7

SDWA-323-revised

Figure 12 Middle River at Undine Bridge Photo 1

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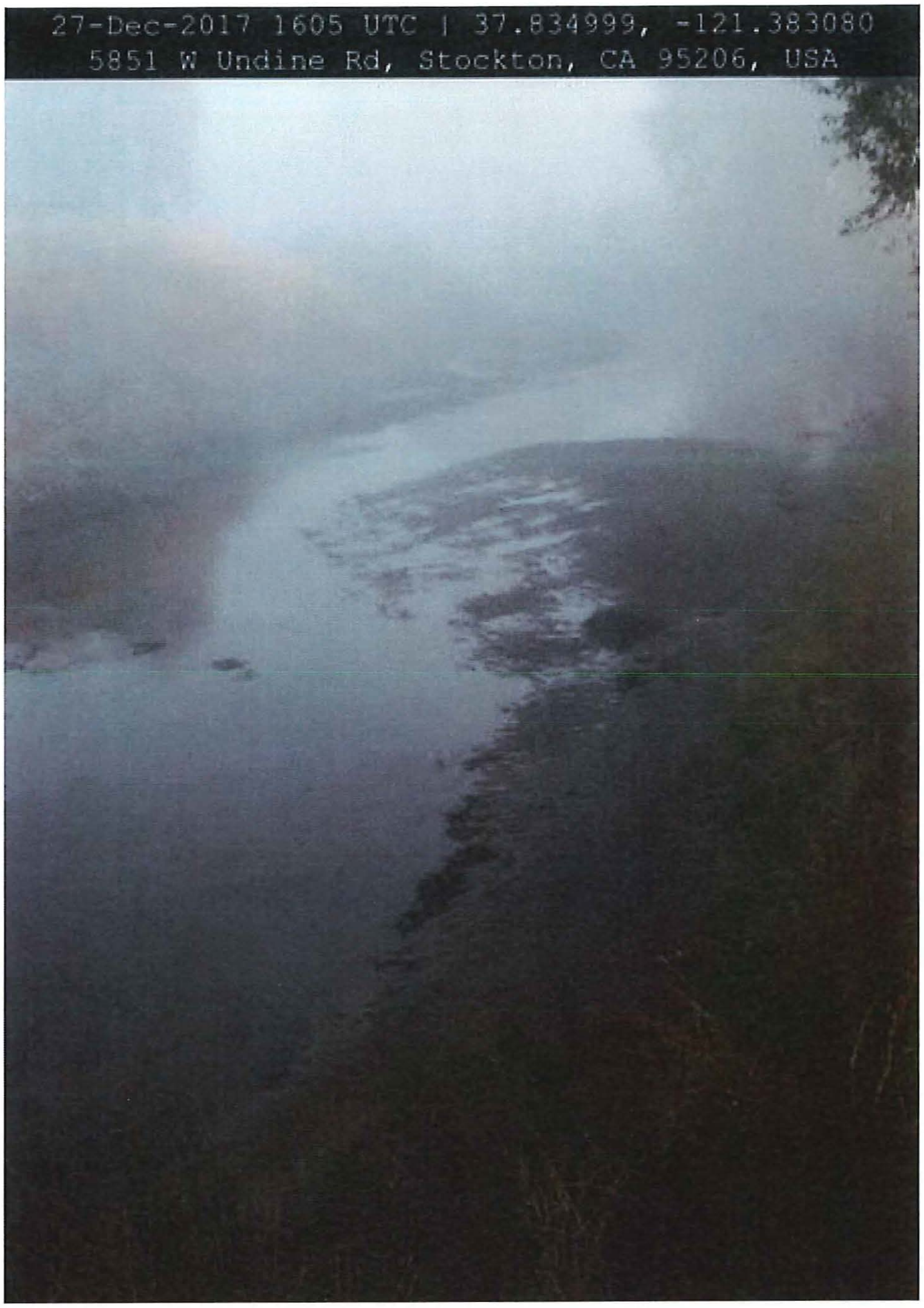

Figure 13 Middle River at Undine Bridge Photo 2

Cross-Sections were also surveyed on Old River and Sugar Cut. Figure 14 is a plan view showing the location of the surveyed cross-sections. As was done with the Middle River cross-sections, the geometry of the DSM2 model at the location of the cross-section was superimposed on the actual surveyed cross-section. Those cross-sections are shown in Figures 15-22. As can be seen in the cross-sections, the Old River cross-sections at the upper end of the river are close to what is represented in DSM2. As you move further downstream, the actual channel geometry and the geometry represented in the DSM2 model start to deviate. In some cases, significantly. Of particular note is OR-4 and OR-6. In these two locations, the actual channel has less than half the cross-sectional area below the mean water line than is represented in the DSM2 model. For the two representative cross-sections surveyed in Sugar Cut, the actual channel geometry only has between one-third to one-half of the flow area as the DSM2 cross-section has below the DSM2 water line. As an example, Figure 22 shows the DSM2 flow area with a solid blue fill. The actual flow area is shown with the diagonal blue cross-hatching. Accordingly, the actual channel will contain between one-third to half of the water shown by the model. Having a smaller flow area will result in a completely different flow rate than what is computed in DSM2. This change in flow rate will affect the movement of salts in the system, and consequently the distribution of salinity concentrations, from those that are computed by DSM2.

Given the significant differences between the existing channel geometry and the channel geometry that is being used in the DSM2 model, it is my opinion that the flow, stage, and water quality data generated by the DSM2 model are not accurate. Major Delta channels that are integral to the accuracy of the hydrodynamic model are incorrectly represented, resulting in the model not being able to provide reliable estimates of the changes that would result from the CWF scenarios. To be used as predictive tool for evaluating changes to flow within the Delta, the model must be able to accurately model the physical processes in the channel system. With incorrect geometry, it is impossible to accurately model those processes. That is not to say it can't be calibrated. Any model can be forced to match existing data by adjusting the calibration parameters until a match is achieved. But if the basic physics of the system are not accurately represented, you only have a model that is calibrated to match the data to which it was calibrated. In my opinion, that type of model cannot be used in a predictive or comparative mode.

There are numerous bathymetric data sets available for Old River and Middle River, going back to 1997 and earlier. Examination of these data sets show that they contain bathymetric data that is much closer to the existing 2018 survey cross-sections than what is presently being used in the DSM2 model. Why the model has not been updated to reflect this collected data, collected as far back as 20 years ago, is unknown. Given the magnitude of potential impacts resulting from the Project, and the amount of resources and capitol that will go into this endeavor, it is imperative that the DSM2 model be updated to accurately reflect the existing conditions in the Delta. Once updated, the CWF scenarios should be re-modeled accordingly.

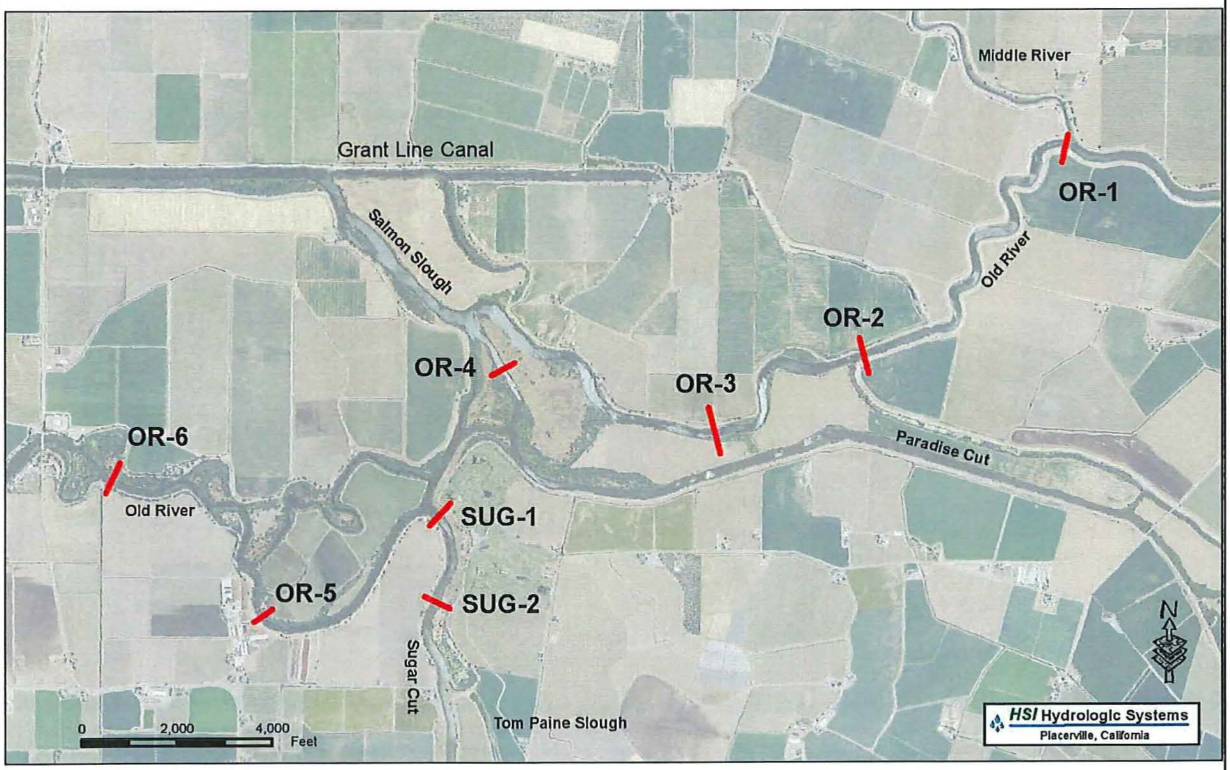

Figure 14 Location of Cross-Sections on Old River and Sugar Cut.

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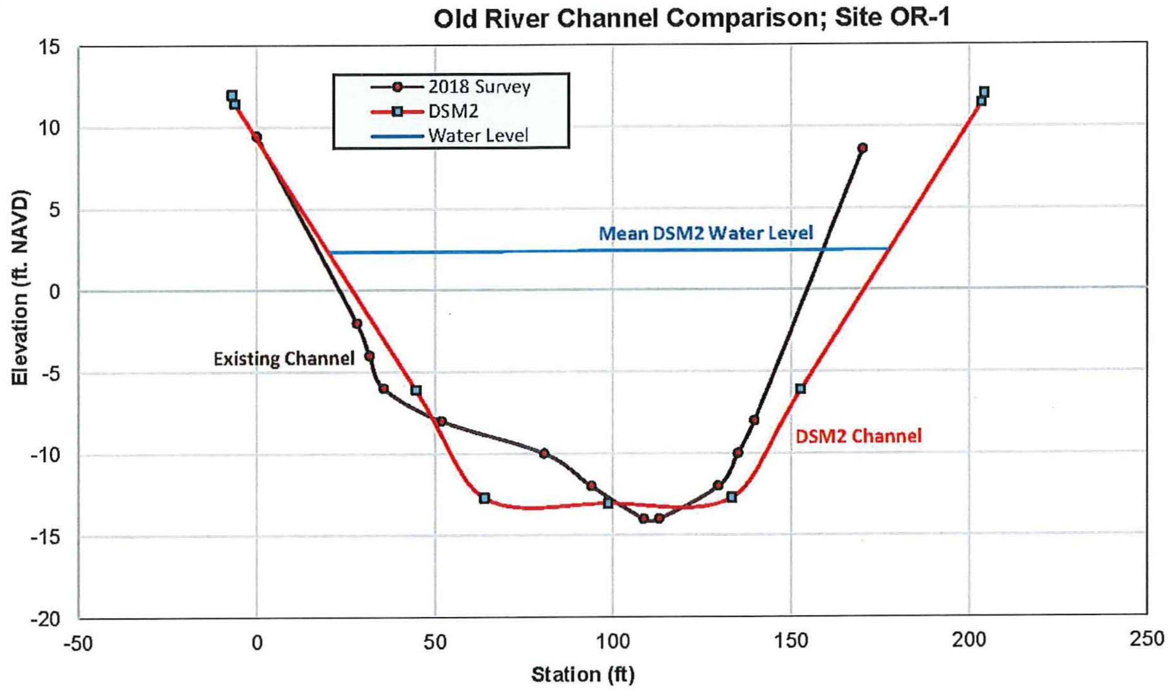

Figure 15 Old River Cross-Section; Site OR-1

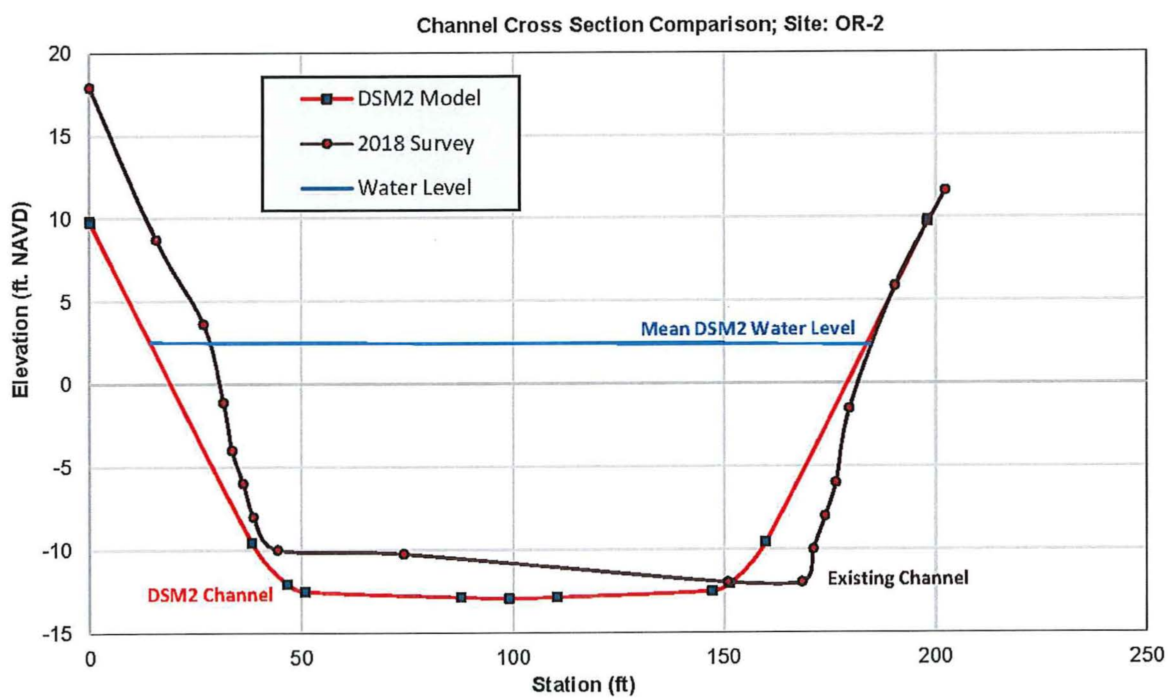

Figure 16 Old River Cross-Section; Site OR-2

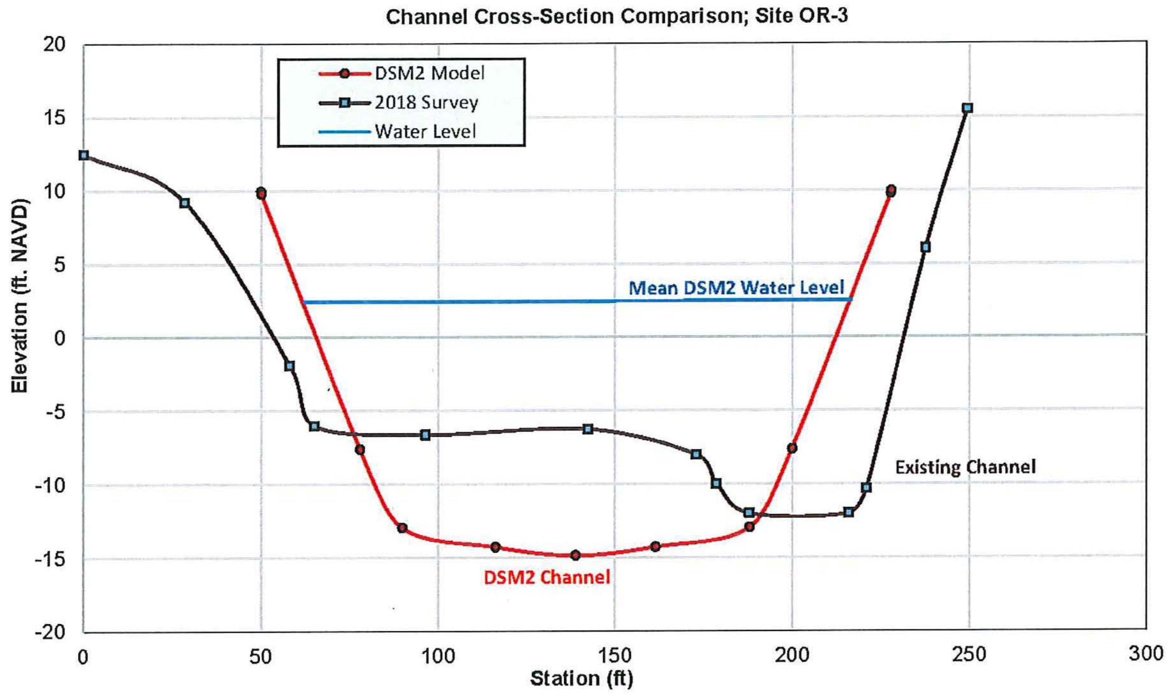

Figure 17 Old River Cross-Section; Site OR-3

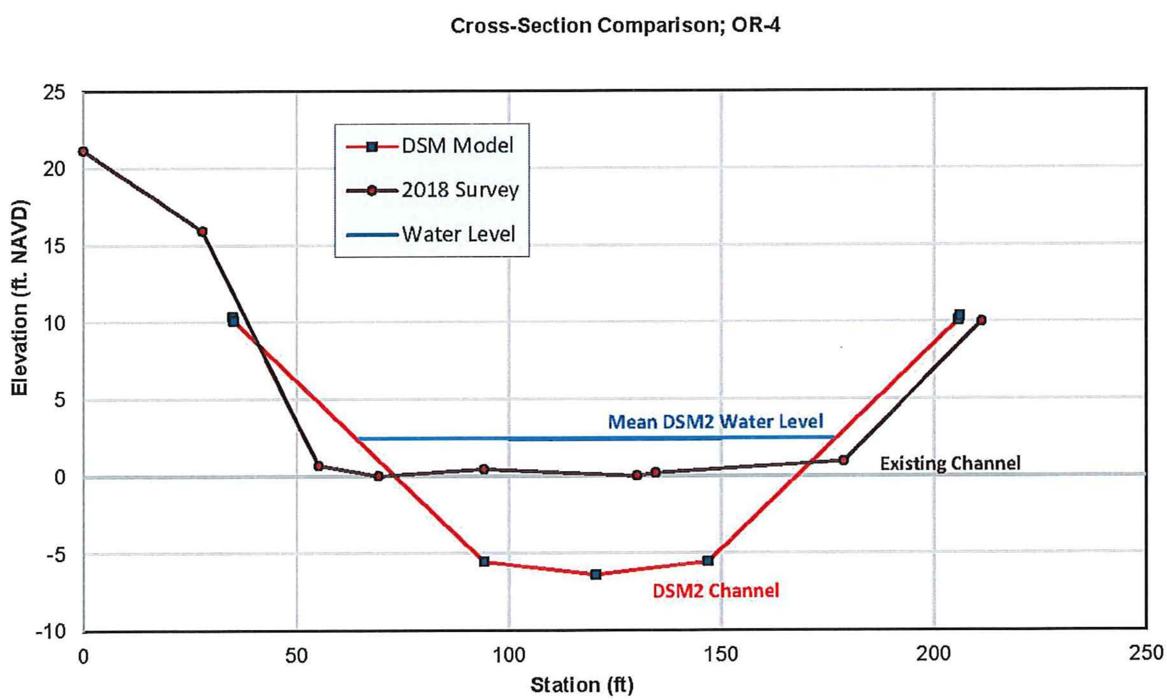

Figure 18 Old River Cross-Section; Site OR-4

SDWA-323-revised

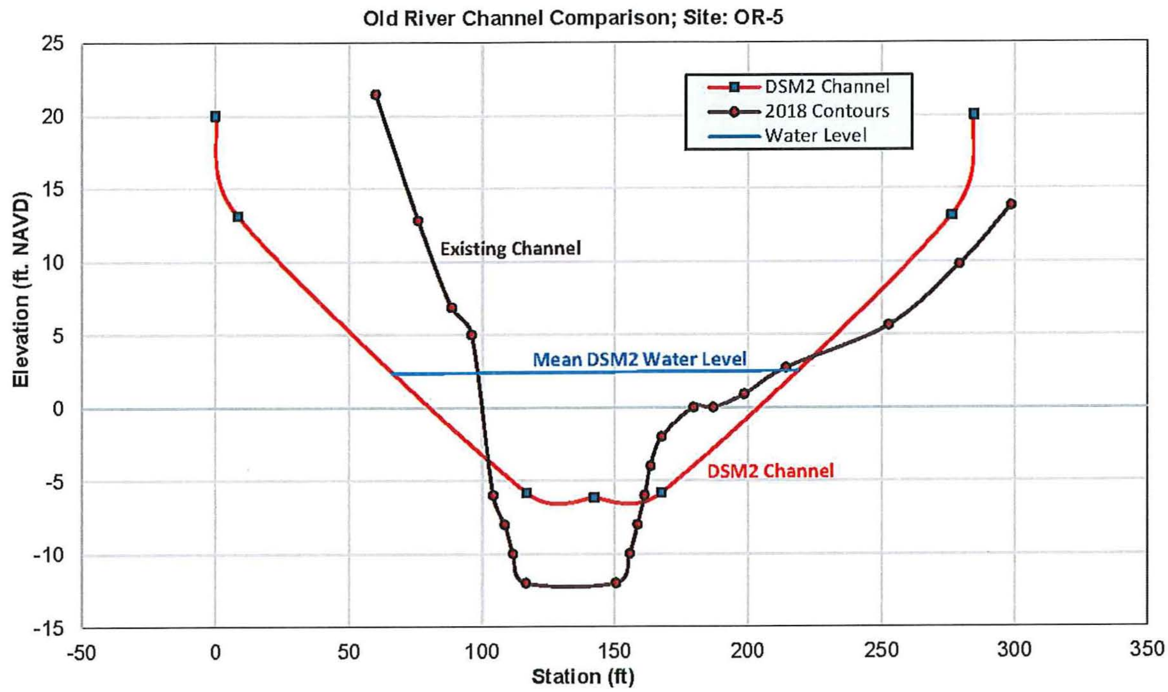

Figure 19 Old River Cross-Section; Site OR-5

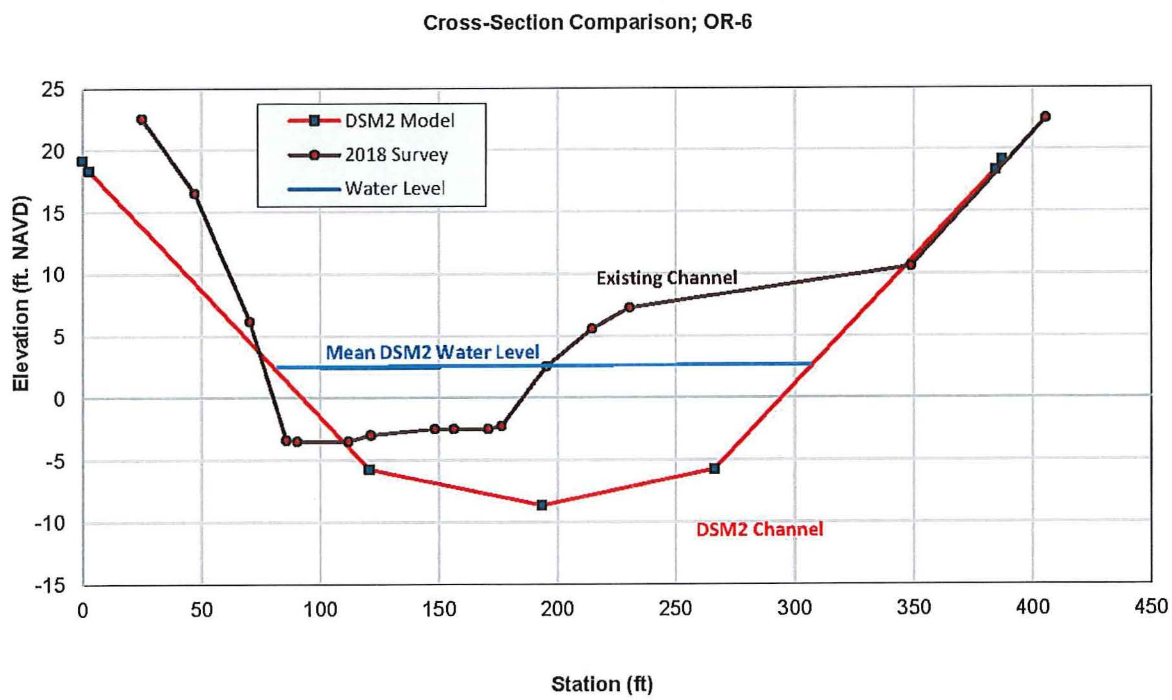

Figure 20 Old River Cross-Section; Site OR-6

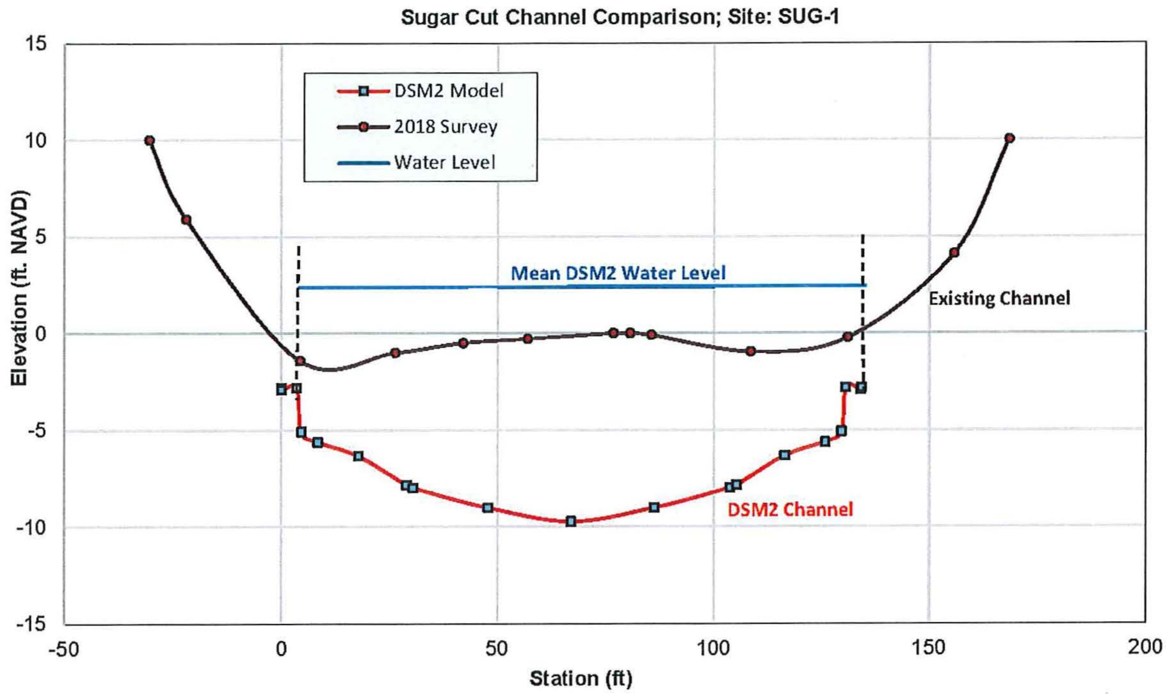

Figure 21 Old River Cross-Section; Site SUG-2

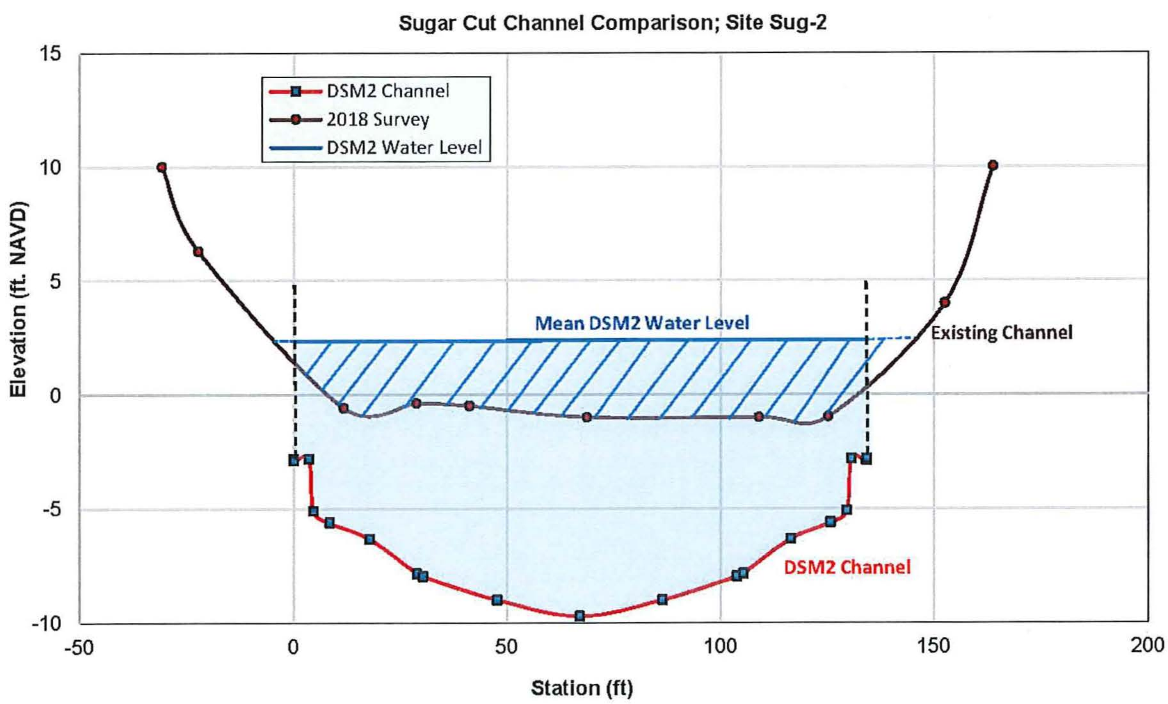

Figure 22 Old River Cross-Section; Site SUG-1

Scenario Evaluation

Defining what constitutes the Project is an important aspect of evaluating its potential impacts. A number of explanations are necessary when reviewing the DSM2 modeling results for the CWF H3+ scenario. A cursory review might leave the impression that the impacts to water quality in the southern Delta resulting from the CWF H3+ operations are small or insignificant. This is misleading. First, the CWF H3+ scenario is still subject to an adaptive management program, yet to be determined. As has been stated in every Part of these hearings, actual operations of the WaterFix Project may change due to adaptive management. The only information we have as to what the adaptive management might look like are the Boundary conditions as originally set forth by Petitioners. Thus, the output from DSM2 as to how the CWF H3+ scenario might affect water quality (and other factors) is only a portion of the analysis. The effects of the WaterFix under the Boundary conditions defined in Part 1 are still also potential effects of the Project. In my Part 1 testimony, I documented how the Water Fix sometimes increases salinity by hundreds of EC depending on the scenario that is being analyzed. Thus, the differences between the effects of H3, H4 or CWF H3+, or BA H3+ must not be assumed to be the only potential impacts of the Project.

Use of DSM2 in Predictive Mode

Thus far there has been confusing testimony from Petitioners regarding the proper use of DSM2. In Part 1, and repeated in Part 2, DWR witnesses asserted the model should only be used in a comparative and not used to predict actual parameters. However, outside of this hearing, DWR routinely uses DSM2 model output to determine if changes in Project operations will adversely affect other users of water. For DWR to assert changing Project operations are not causing additional violations of water quality standards, DWR uses the model to "predict" that the modeled change will not raise the EC above a specified standard. Used in this way, DWR is in fact using the model to predict what the actual EC will be under a given operational scenario.

As an example, Exhibit SDWA-325 is a June 26, 2018 email from DWR, with attachments, addressed to various parties, including, South Delta Water Agency, showing model results from a potential water transfer. It is my understanding that pursuant to the Water Level Response Plan (SDWA-11) required by D-1641, DWR is required to model the effects of any proposed water transfer on water quality and water levels. The graphs attached as exhibits to SDWA-325 show the modeled change in EC, and for a short segment of that time, the actual measured EC. As plotted on the graphs, DSM2 incorrectly predicts water quality at each of the 4 locations: at Holland Ct by approximately 75 EC on June 19, 2018; at Old River at Middle River by approximately 200 EC on June 24, 2018; at San Joaquin River Brandt Bridge by approximately 50 EC on June 22, 2018; and at Old River at Tracy Road by approximately 150 EC on June 20, 2018. The difference between the actual salinity and the modeled (predicted) salinity varies significantly from site to site.

Based on these results, when The Petitioners assert that their averaged modeling results indicate little or no additional violations of the D-1641 salinity standards in the southern Delta one simply cannot determine what the actual increase may be with respect to the D-1641 standards.

Further, we see that on the Holland Ct, Old River near Middle River and Old River at Tracy Road graphs, sometimes the DSM2 model is predicting an increase in EC when the measured data is showing a decrease (and vice versa). One of the first principals required of a model to be used in a comparative or predictive mode is that as a minimum it be able to track trends in the parameter that it is modeling. If the model cannot reliably determine whether EC is increasing or decreasing, it is not capable of modeling the basic physics of the system. Given the obvious and very recent inaccuracy of the DSM2 model, it is very difficult to reach any meaningful conclusions about the comparative effects of the CWF as compared to the NAA.

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Impact Assessment on Crops

With regard to how one should interpret these modeling data for CWF H3+, SDWA et.al. presented evidence in Part 1 (SDWA-92 Prichard) that effects on crops or plants was not measured by changes in the applied water quality alone (i.e. the DSM2 outputs) but was determined by how any such changes affect the soil salinity of the crop.

D-1641 Compliance

In his Part 2 testimony, Mr. Reys states that the CWF H3+ complies with the Water Rights Decision D-1641. This is not true in the South Delta. The salinity criteria at the Old River at Tracy compliance point is routinely exceeded. Figure 23 is a plot of D-1641 exceedance data. The data that this plot was based on Petitioners exhibit DWR-402.

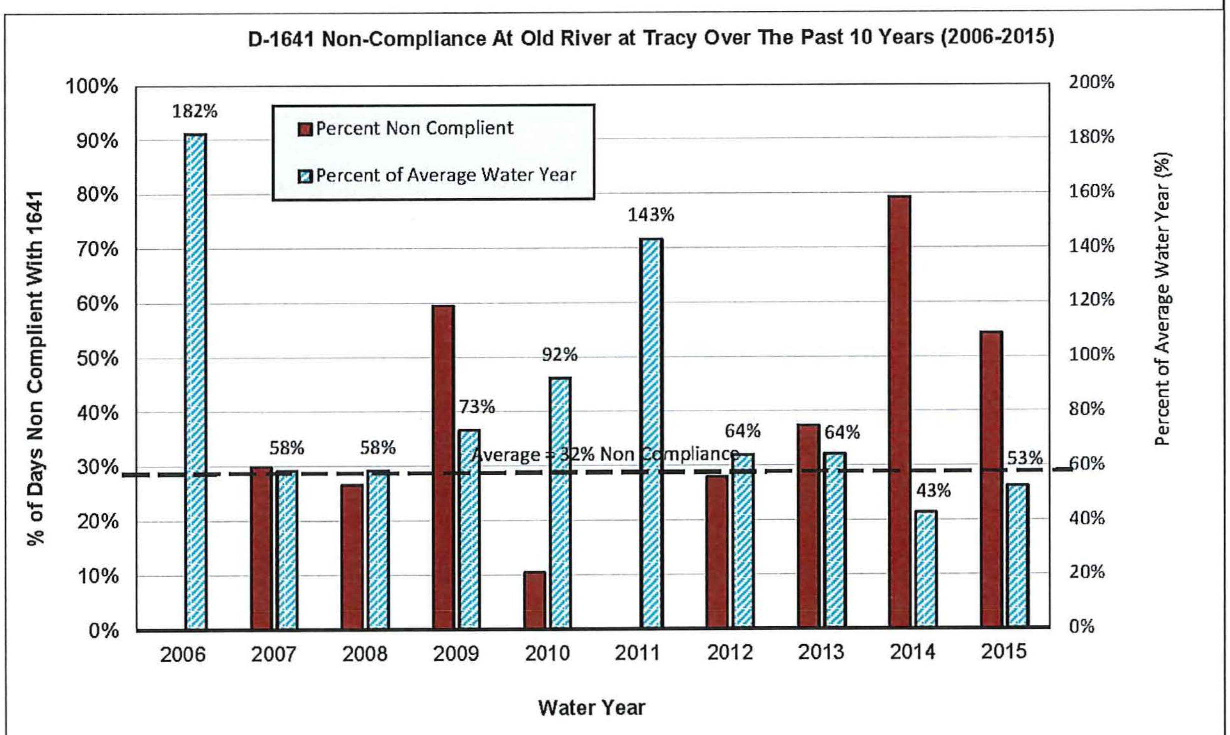

Figure 23 Existing Condition Compliance of D-1641 At Old River At Tracy Compliance Point

As demonstrated by Figure 23, there is a significant non-compliance with the D-1641 requirements at the Old River at Tracy. The only years that the Petitioners were in compliance were in above normal water years. As I have shown in the sections above, the CWF H3+ will result in an increase in salinity in the South Delta. This increase in salinity will only increase the amount of time that the Petitioners will be in non-compliance. Their inability to come into compliance at this location may be the result of the geometry errors that are incorporated into the DSM2 model in the South Delta.

The CWF H3+ alternative results in an increase in reverse flows that will experienced on Old and Middle Rivers. As was shown in my Part 1 rebuttal testimony, the reverse flows will increase across the South Delta except for the San Joaquin River. Details of this analysis were provided in SDWA-257. In that analysis, the net downstream flow decreased from between 26 to 51 percent. The claim by Mr. Reyes that the CWF complies with the 2008 and 2009 BO's is not born out by the modeling results. It should be noted that given the inaccurate geometry in the model, especially in Middle River, there is truly no way to know what the flow is, or if the requirements of the BO's are being met.

In Ms. Smith's Part 2 testimony, she states that the CWF H3+ and BA H3+ have no significant impact on water levels as compared to the NAA. That statement is incorrect. I demonstrated in my Part 1 rebuttal testimony that, using the Petitioners own model, that water level reductions of up to 3 feet will occur in Old and Middle Rivers. At the upper end of Old River, the water level will be lowered by over 1.36 feet 20% of the time. This analysis was based on the geometry in the DSM2 model that we now know is incorrect. If the model were to be updated to reflect the actual geometry, that reduction may be much larger. That could result with Project operational scenarios resulting in sections of the channel, which are almost going dry now, to completely dry up during parts of the year.

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Cold Water Entering The Delta

In his written testimony for Part 2 of this hearing (DWR-1017), Dr. Bryan stated that the Sacramento River water is in equilibrium with the air temperature by the time that it reaches the delta. An analysis of the water and air temperature at Freeport on the Sacramento River shows that to not necessarily be the case. The daily water temperature and flow data, acquired from DWR's CDEC web site for the Freeport Gaging station on the Sacramento River. These data were compared to the daily air temperature collected at California State University in Sacramento. The daily data were compared over the Dec 2009 to July 2018 period. The air temperature, water temperature, and Sacramento River flow were compared separately for the months of June, July, and August. Figures 24 through 26 are plots of the data for those months.

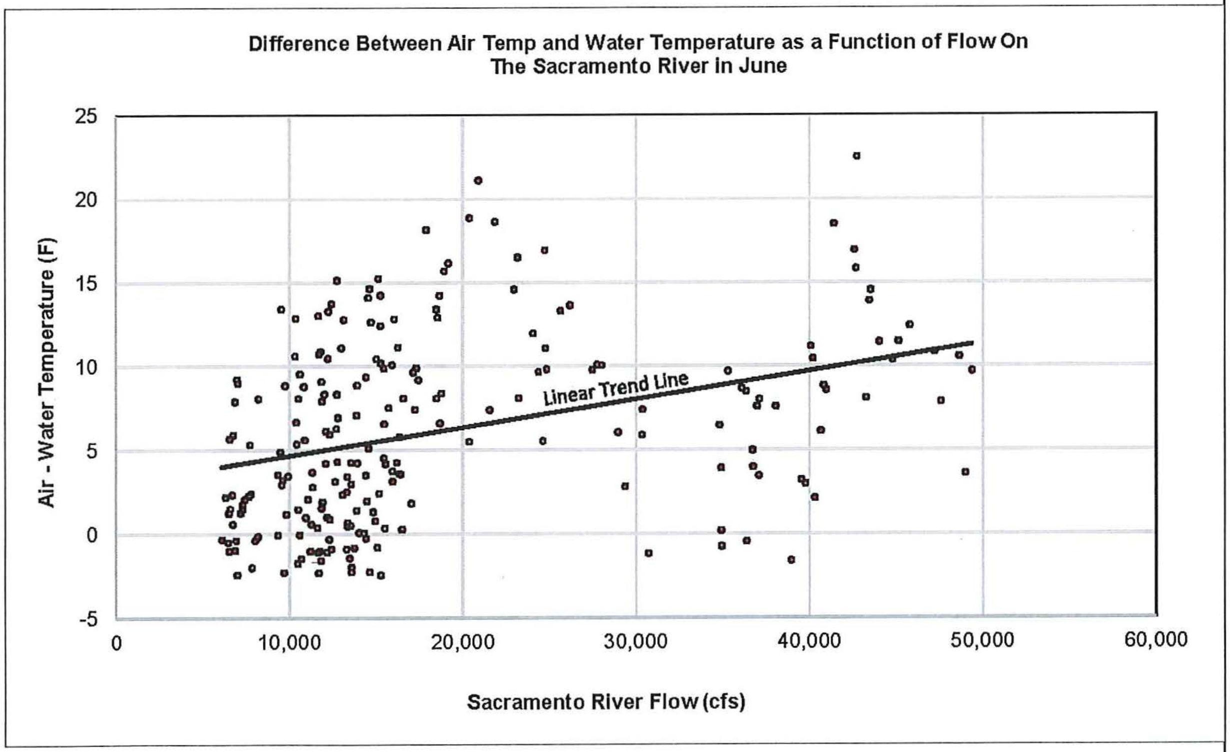

Figure 24 Difference Between the June Air and Water Temperature As A Function of Flow on the Sacramento River At Freeport.

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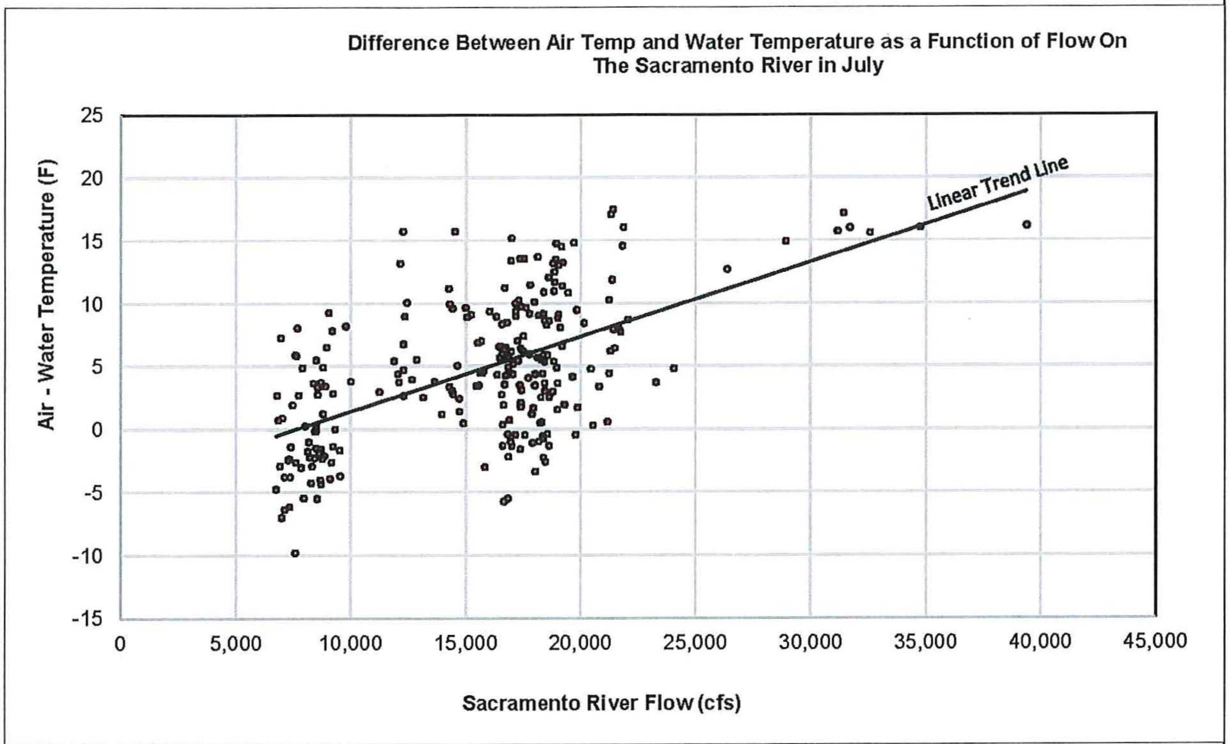


Figure 25 Difference Between the July Air and Water Temperature As A Function of Flow on the Sacramento River At Freeport.

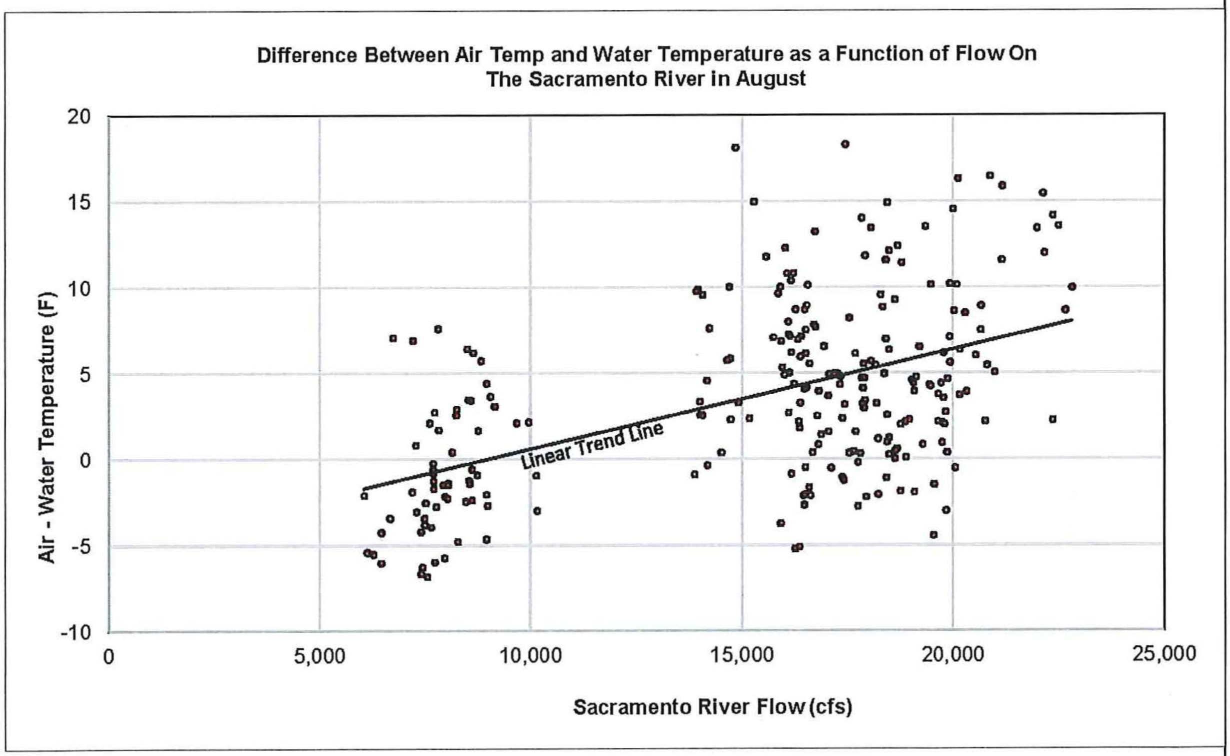


Figure 26 Difference Between the August Air and Water Temperature As A Function of Flow on the Sacramento River At Freeport.

As can be seen from the figures, the air temperature is often between 5 and 10 f degrees warmer than the water temperature. That temperature difference typically increases as the flow in the Sacramento river increases. The difference is less than 5 degrees when the Sacramento River flow is low. During these low flow periods, the air and water temperature would be better able achieve a relationship closer to an equilibrium condition. This information seems to indicate that the Sacramento River may not be in equilibrium with the air temperature. If it were, the trend line for each month's data would be roughly horizontal. Dr. Bryan testified that it was not necessary to look at actual data to determine if the Sacramento River was in equilibrium with the air temperature. This measured data set, covering 9 years of actual daily flow and temperature, seems to indicate that the river may not be in equilibrium with the air temperature.

No actual data was reviewed by the Petitioners expert, Dr. Bryan. When asked during his testimony if he reviewed any actual data, his response indicated that looking at actual data would not be relevant. We have a suite of models that we rely upon.

If the Sacramento River flow is not in equilibrium with the air temperature, it would provide a source of cool water to the Delta that could be beneficial to aquatic habitat, and provide a delaying action to the development of HAB's. Removal of this water through the NDD's will remove the supply of cool water entering the Delta.

VI. Conclusion

Analysis of the data from the Petitioners models, and published data from DWR, seems to refute many of the statements that were provided in the Petitioners testimony in the Part 2 of this hearing. After careful evaluation of the available data I have come to the following conclusions.

- The CWF H3+ does not comply with the water quality objectives of D-1641. Granted, the NAA also does not meet the D-1641 objectives, but with the documented increase in salinity that was shown to occur in the B1, B2 scenarios from my Part 1 testimony, and the increases that will occur in the CWF H3+ scenario, the Project will be out of compliance more often, and to a greater degree.

- The CWF H3+ will result in an increase in the number of reverse flows in Old and Middle River. Analysis of the Petitioners DSM2 output shows a 22% increase in reverse flows on Old River at Tracy for the CWF H3+ over the NAA.

- Based on the Petitioners modeling, the CWF H3+ will result in an increase in salinity for all locations evaluated in the South Delta, except for the San Joaquin River.

- The DSM2 model has some very inaccurate representations of the channel geometry in the South Delta. This inaccurate representation of channel geometry will force an inaccurate distribution of flows, water quality and depth. The error in geometry is so bad in the Middle River as to render any modeling results completely inaccurate.

- The CWF H3+ will result in significant reductions in water level in rivers in the South Delta. This reduction in water level can impact habitat, ability to irrigate, and water quality.

- Using the DSM2 model to evaluate different scenarios on a 15-minute time step, is not only appropriate, but is using the DSM2 model the way it was designed to be used. The 15-minute time step is required to capture the diurnal fluctuation of the tide as it varies throughout the day. This 15-minute data can be averaged over longer periods, but the longer the period that that you use to average the data, the more detail you lose in the model response. In a comparison of scenarios, you want to use the smallest time step necessary, and practical, to capture the natural variability that is driven by the input data.

- The assumption that the Sacramento River is in thermal equilibrium with the air temperature may not be correct. Thus, removing this cooler water through the NDD's may have downstream impacts. No actual data was evaluated to determine if the system was in thermal equilibrium. Based on actual data there is often a 5 to 10-degree difference between air and water temperature on the Sacramento River at Freeport. This difference between air temperature and water temperature is large enough to suggest that the stream may not be in equilibrium. If it is not in equilibrium, pulling cool water out of the river at the NDD's would deprive the Delta downstream of cool water. This could have impacts on habitat and algal growth within the area that is affected by this cooler water.

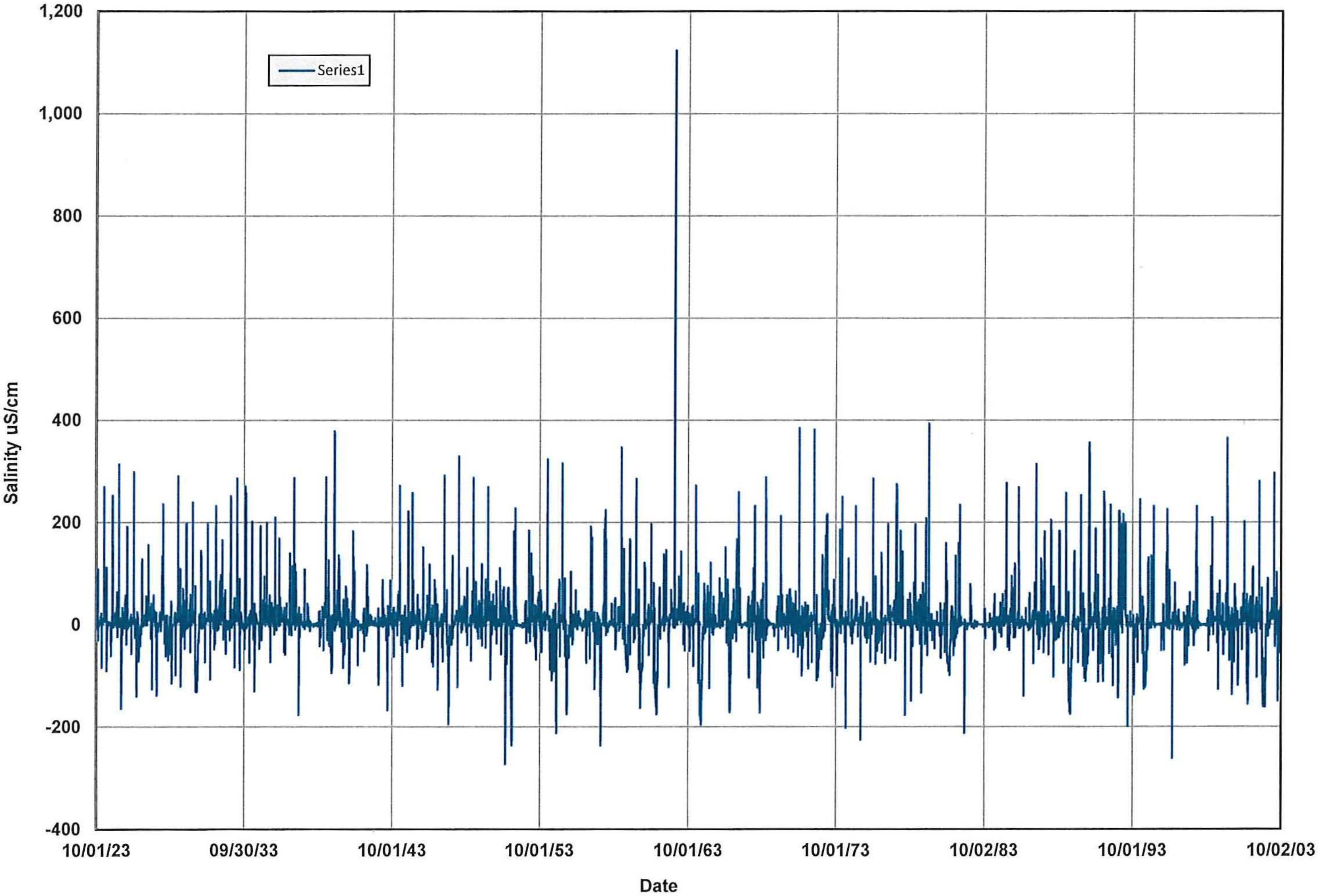
Executed on the 12th day of July 2018, at Placerville, California.

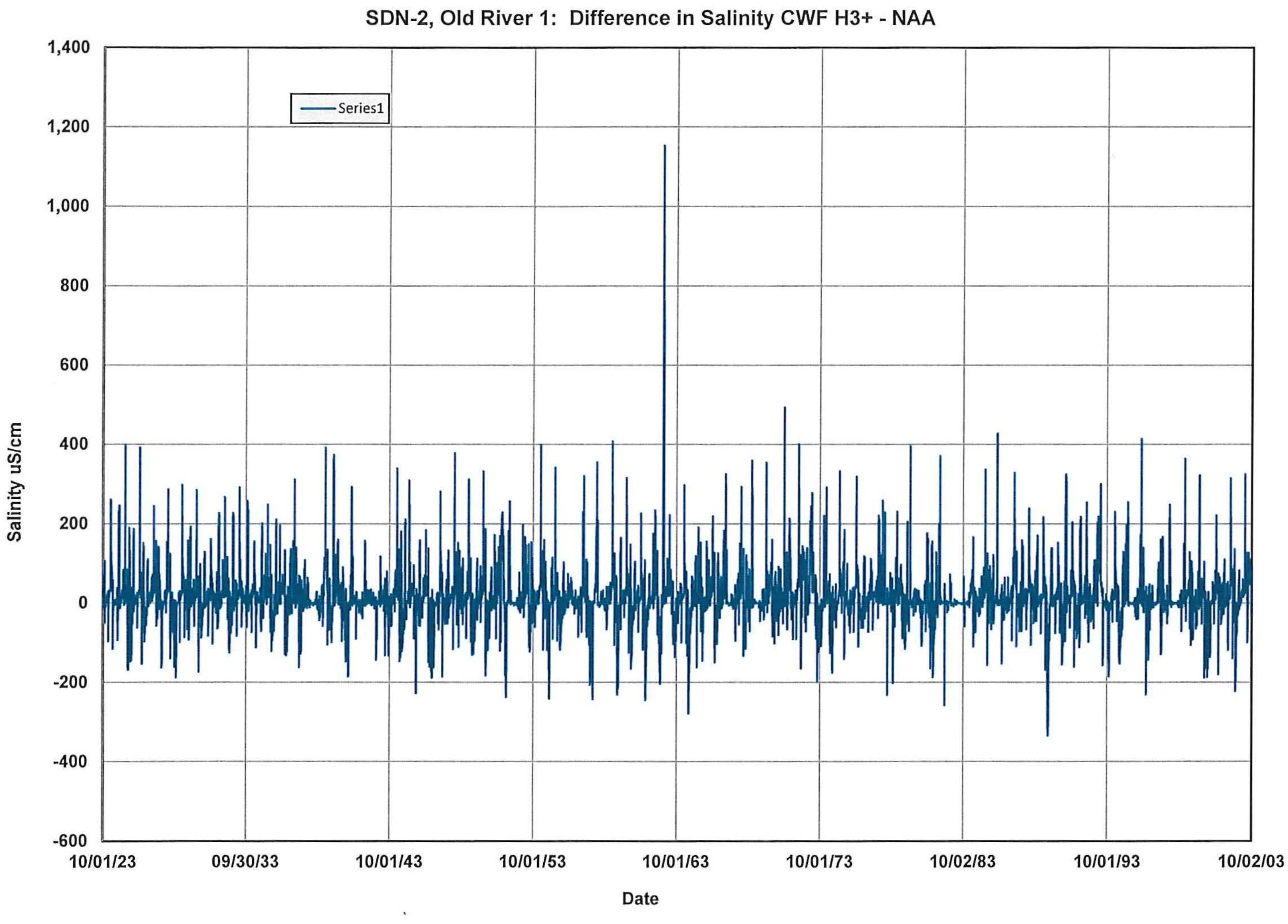
Thomas K. Burke

THOMAS K. BURKE, P.E.

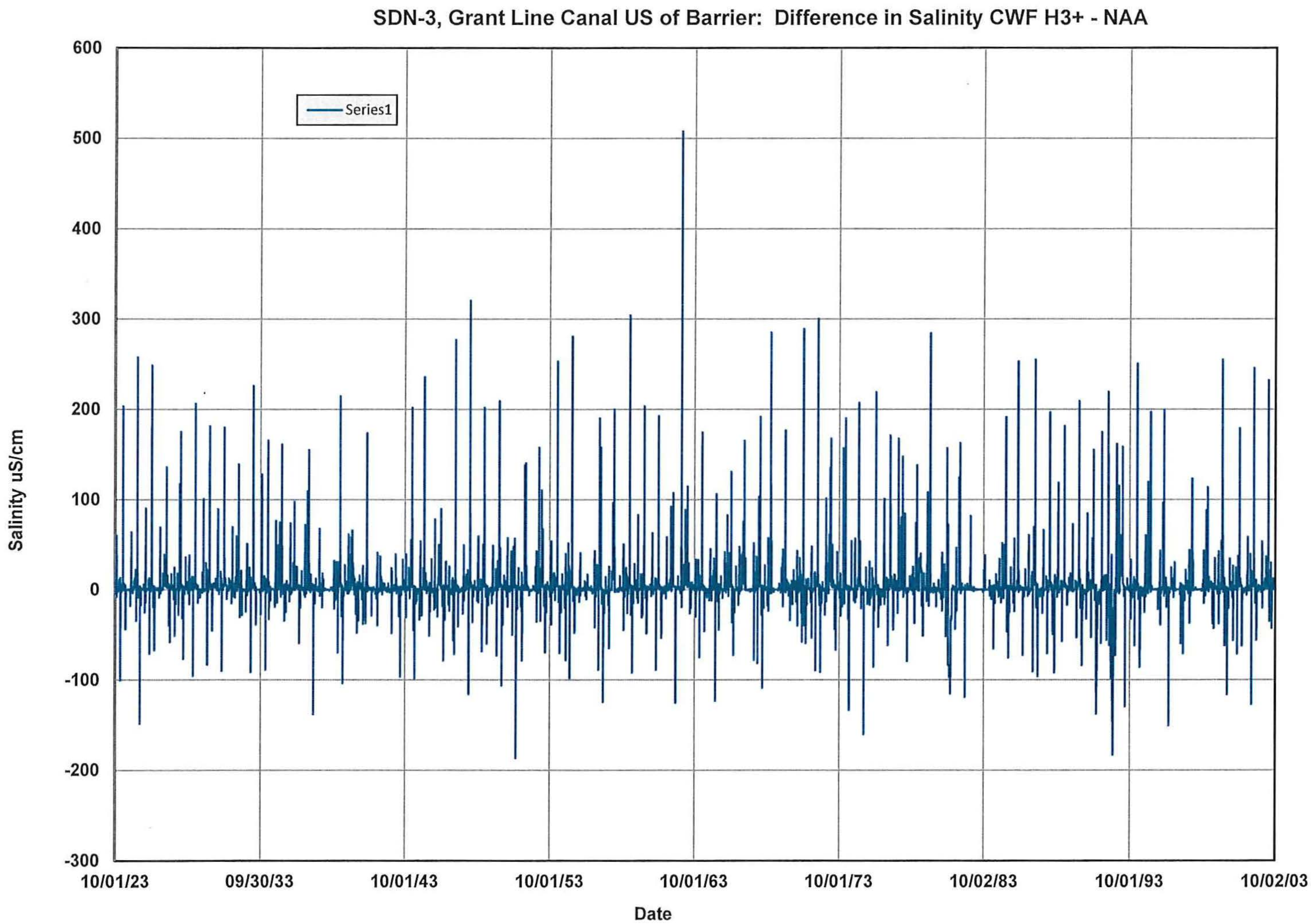
Appendix A – Salinity Difference Plots

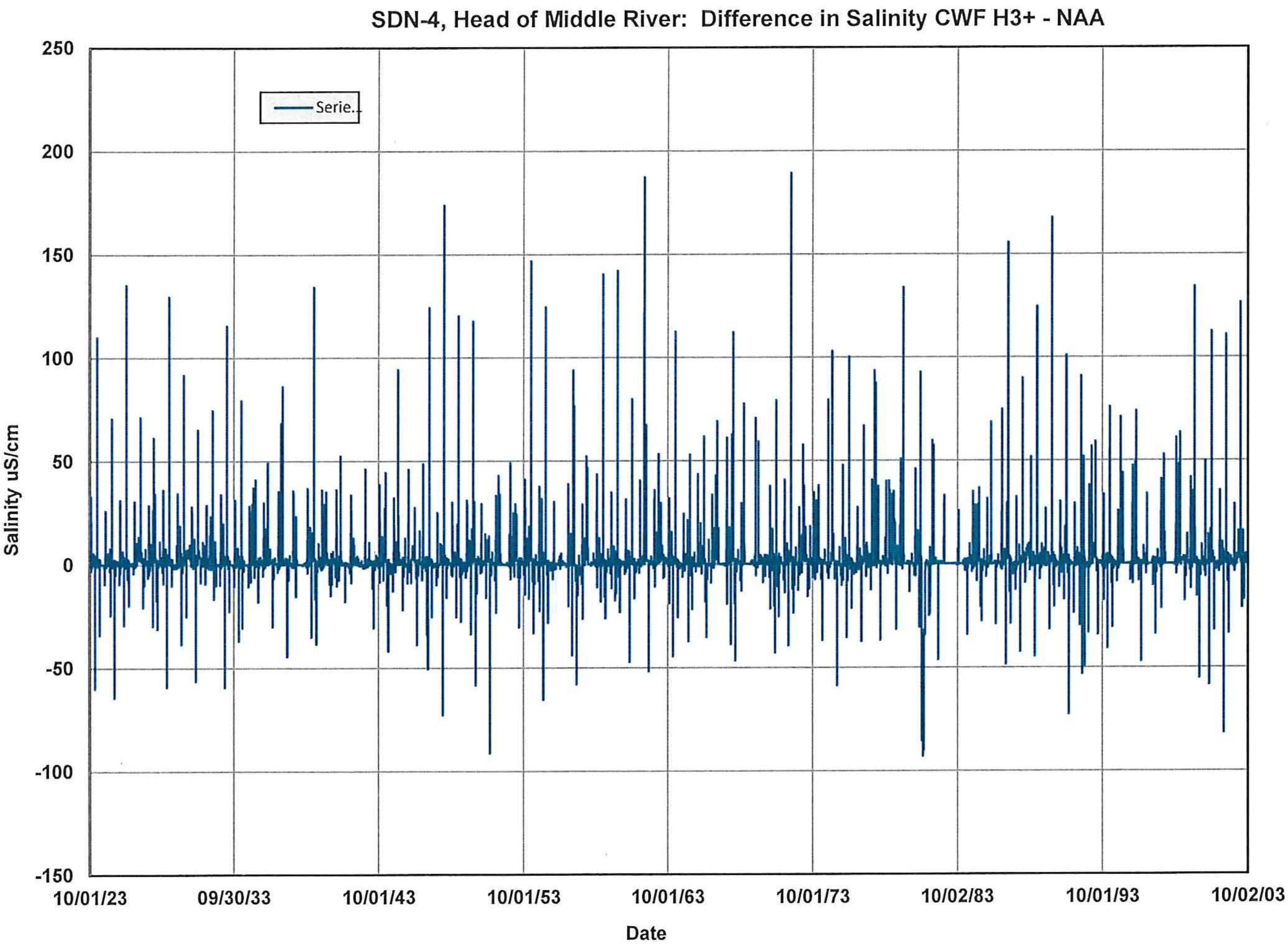
SDN-1 Old River at Tracy: Difference in Salinity CWF H3+ - NAA



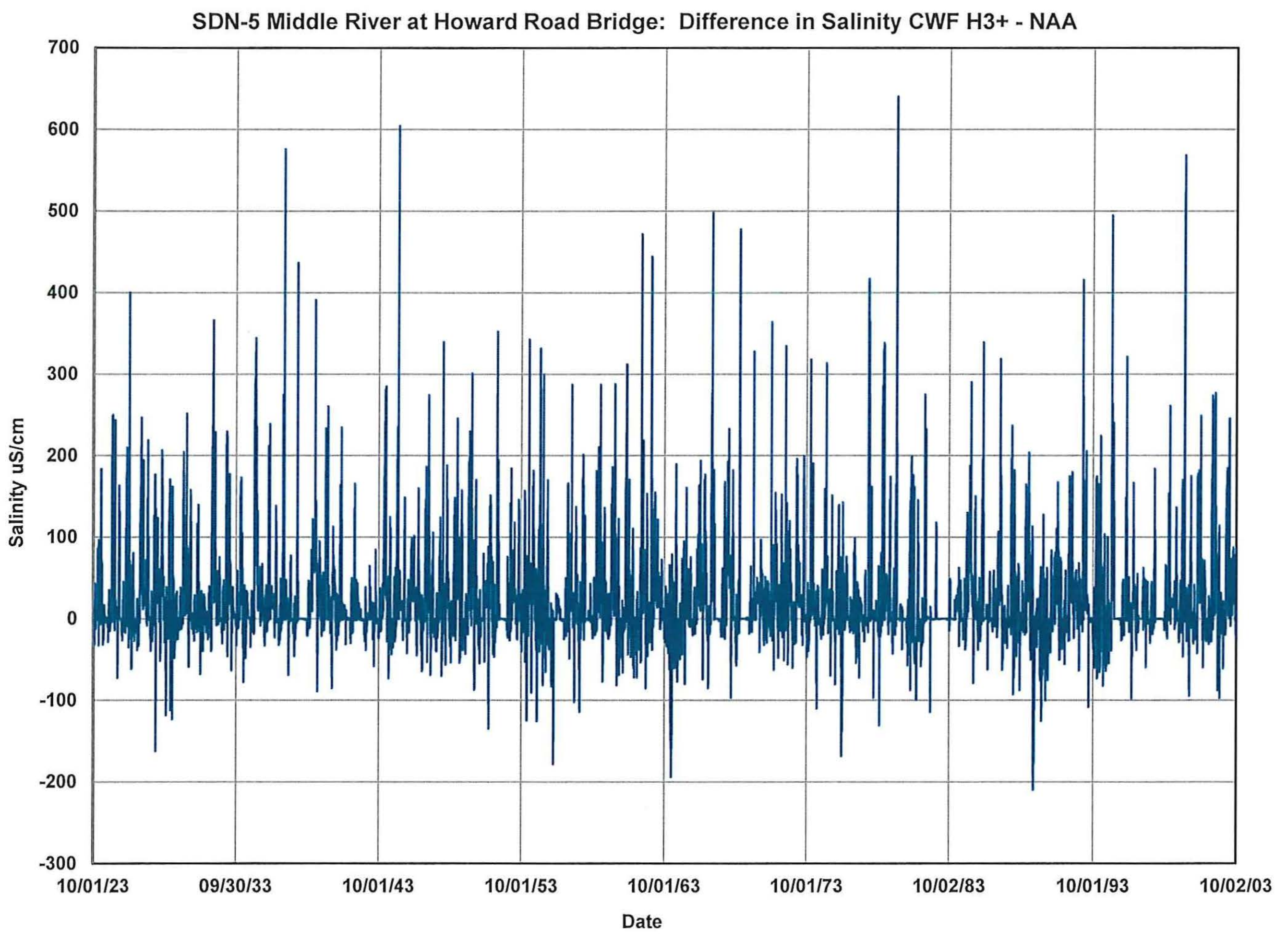


SDN-2, Old River 1: Difference in Salinity CWF H3+ - NAA
Series1
1,400
1,200
1,000
800
600
400
200
0
-200
-400
-600
Salinity uS/cm
10/01/23
09/30/33
10/01/43
10/01/53
10/01/63
10/01/73
10/02/83
10/01/93
10/02/03
Date

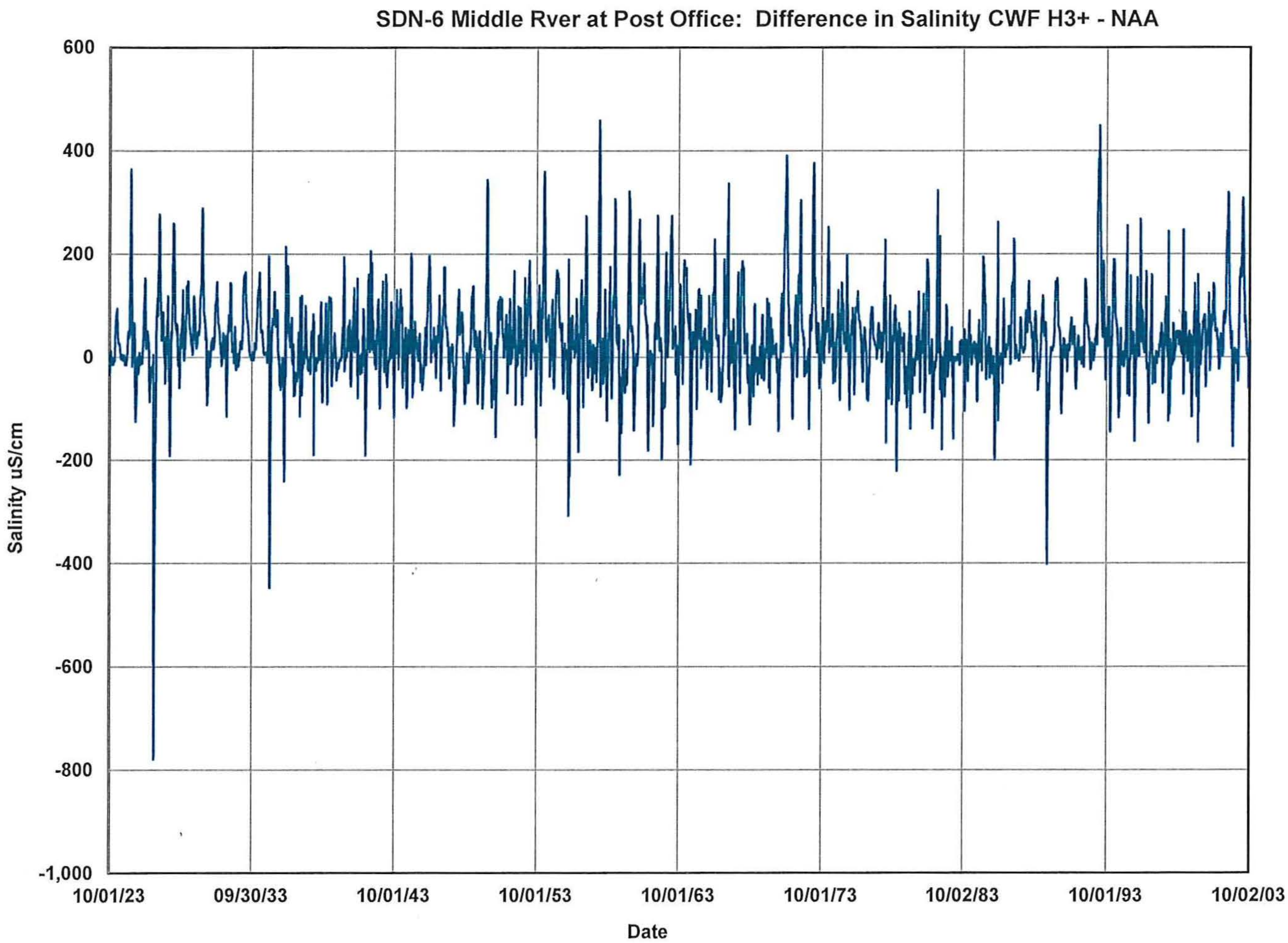

SDN-3, Grant Line Canal US of Barrier: Difference in Salinity CWF H3+ - NAA
Series1
600
500
400
300
200
100
0
-100
-200
-300
Salinity uS/cm
10/01/23
09/30/33
10/01/43
10/01/53
10/01/63
10/01/73
10/02/83
10/01/93
10/02/03
Date



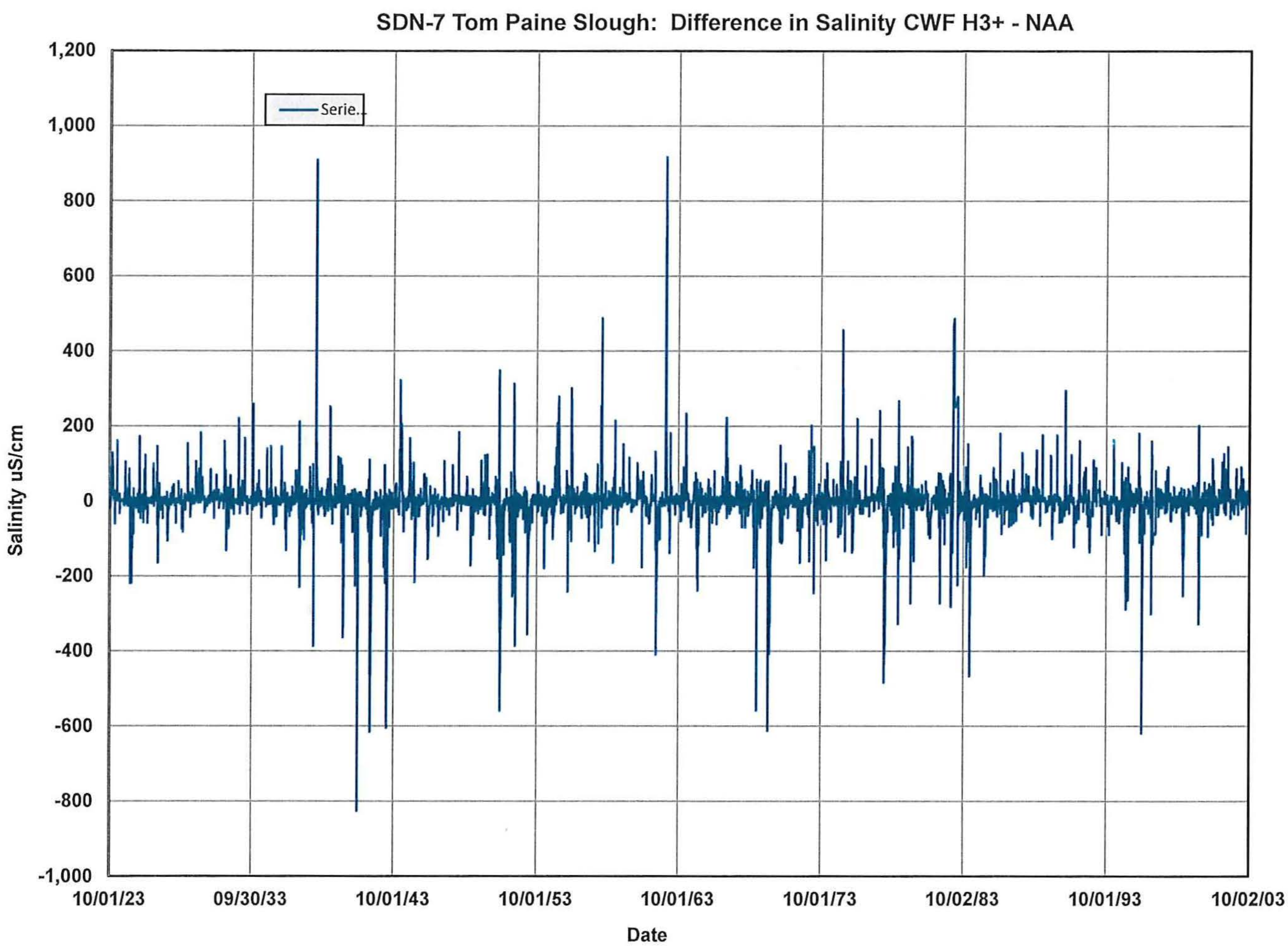
SDN-4, Head of Middle River: Difference in Salinity CWF H3+ - NAA
Serie...
250
200
150
100
50
0
-50
-100
-150
Salinity uS/cm
10/01/23
09/30/33
10/01/43
10/01/53
10/01/63
10/01/73
10/02/83
10/01/93
10/02/03
Date



SDN-5 Middle River at Howard Road Bridge: Difference in Salinity CWF H3+ - NAA
700
600
500
400
300
200
100
0
-100
-200
-300
Salinity uS/cm
10/01/23
09/30/33
10/01/43
10/01/53
10/01/63
10/01/73
10/02/83
10/01/93
10/02/03
Date

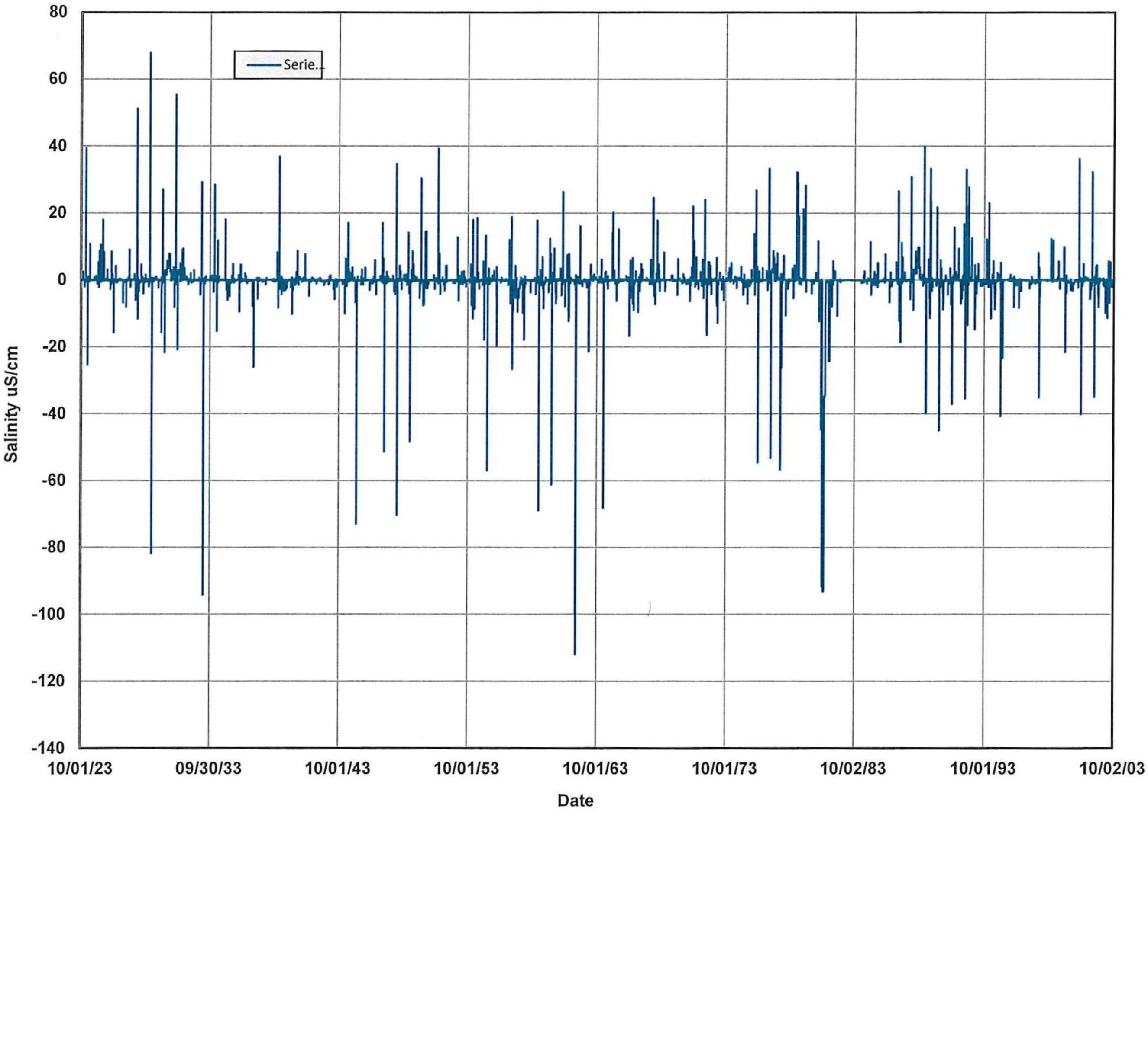


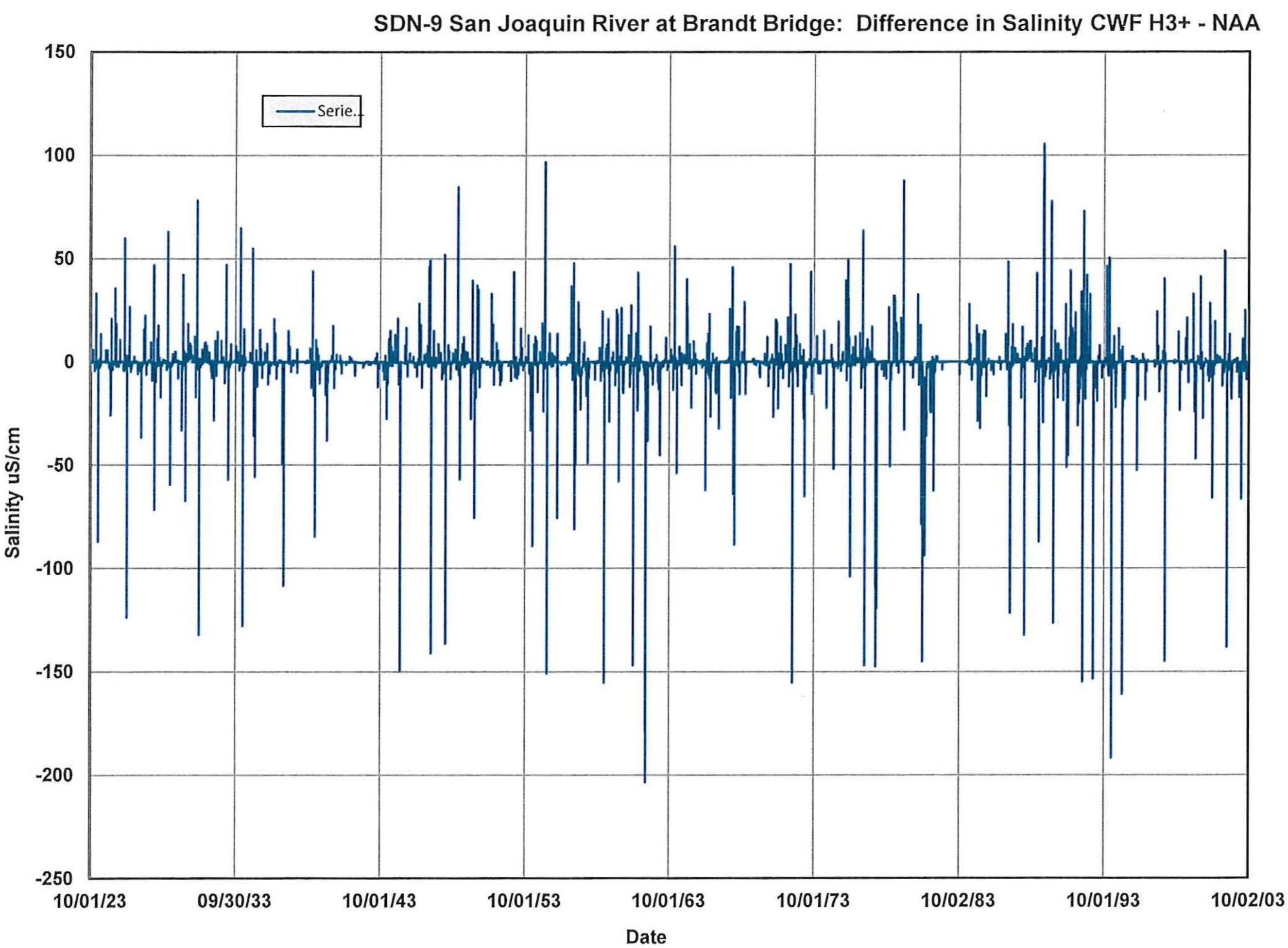
SDN-6 Middle Rver at Post Office: Difference in Salinity CWF H3+ - NAA
600
400
200
0
-200
-400
-600
-800
-1,000
Salinity uS/cm
10/01/23
09/30/33
10/01/43
10/01/53
10/01/63
10/01/73
10/02/83
10/01/93
10/02/03
Date



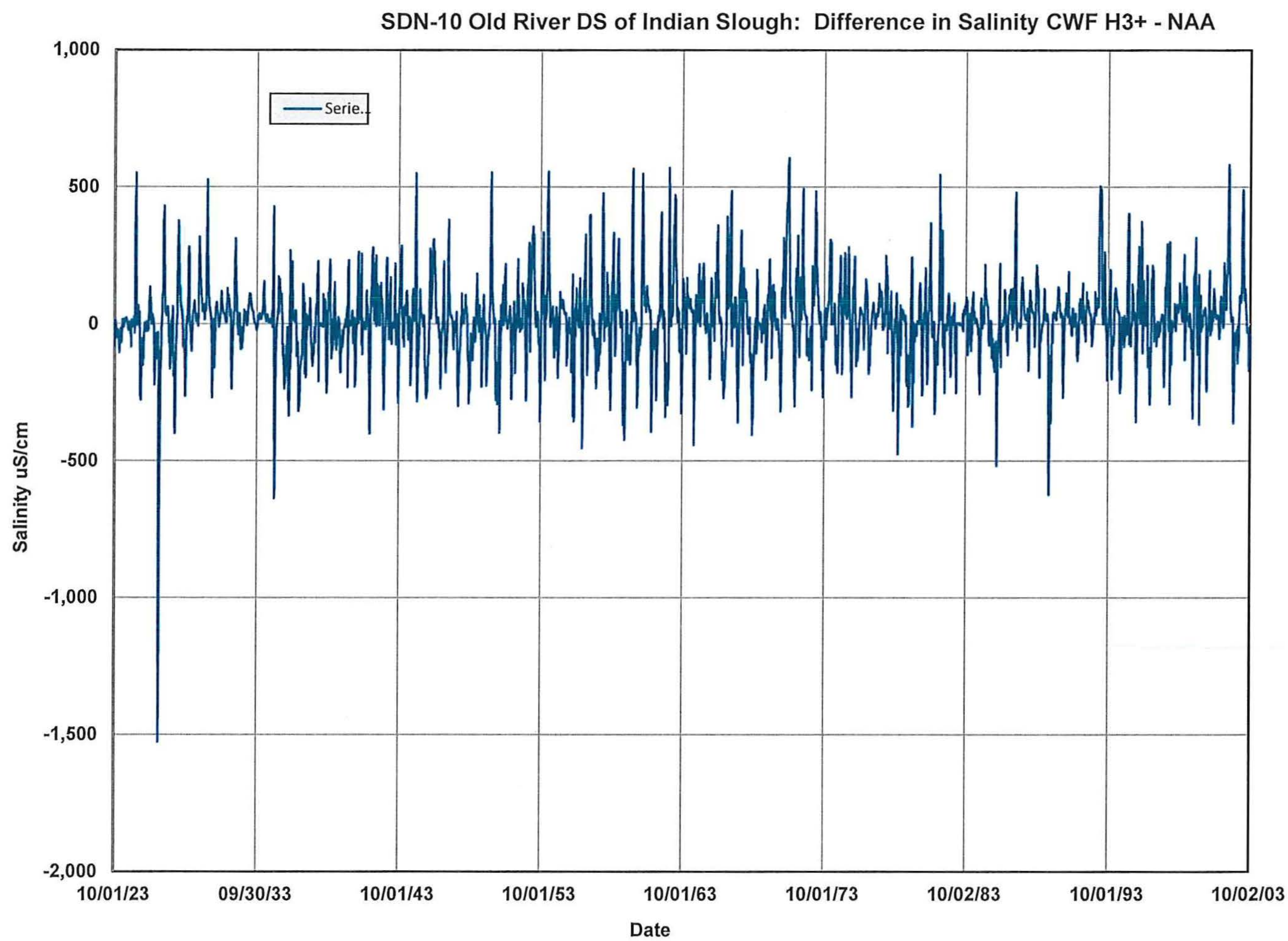
SDN-7 Tom Paine Slough: Difference in Salinity CWF H3+ - NAA
Serie...
Salinity uS/cm
1,200
1,000
800
600
400
200
0
-200
-400
-600
-800
-1,000
10/01/23
09/30/33
10/01/43
10/01/53
10/01/63
10/01/73
10/02/83
10/01/93
10/02/03
Date

SDN-8 San Joaquin River 1: Difference in Salinity CWF H3+ - NAA





SDN-9 San Joaquin River at Brandt Bridge: Difference in Salinity CWF H3+ - NAA
Serie...
150
100
50
0
-50
-100
-150
-200
-250
Salinity uS/cm
10/01/23
09/30/33
10/01/43
10/01/53
10/01/63
10/01/73
10/02/83
10/01/93
10/02/03
Date


SDN-10 Old River DS of Indian Slough: Difference in Salinity CWF H3+ - NAA
Serie...
1,000
500
0
-500
-1,000
-1,500
-2,000
Salinity uS/cm
10/01/23
09/30/33
10/01/43
10/01/53
10/01/63
10/01/73
10/02/83
10/01/93
10/02/03
Date