Technical Report

September 2016

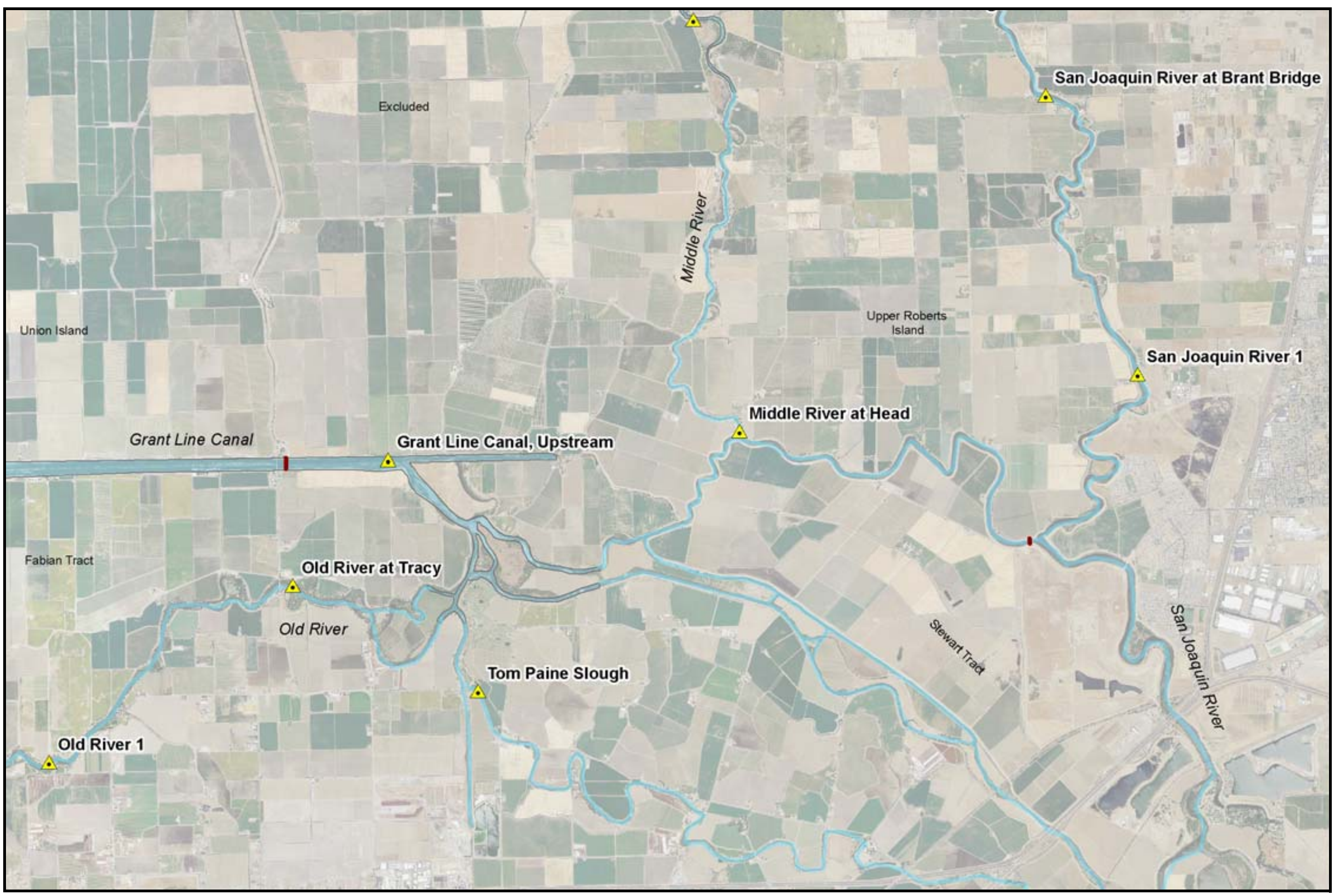
Evaluation of Impacts From The California Water Fix on The Central and South Delta

Prepared By:

HSI **Hydrologic Systems**
936-B 7th Street, Suite 303
Novato, California 94945

Prepared For:

The South Delta Agency Parties
4255 Pacific Avenue, Suite 2
Stockton, California 95207



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4255 Pacific Avenue, Suite 2
Stockton, California 95207

Signed: Thomas K. Burke Date: September 1, 2016

Thomas Burke P.E., Registered Civil Engineer
License No. C 50051, Expires 6/2017

September 2016 Project No. 1373

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1. Introduction

The California Department of Water Resources (DWR) and the Bureau of Reclamation (BOR) are advocating for the implementation of the California Water Fix (CWF) Project. The CWF would divert a substantial amount of water from the north Delta through subsurface twin tunnels for delivery to significantly expanded south Delta export facilities. As such, a significant amount of water which now flows through the Delta would bypass the Delta and be conveyed through the twin tunnels. The CWF proposes four initial operational scenarios, including two boundary scenarios which bracket the minimum and maximum amounts of water which would be exported from the Delta as a result of the CWF. A Plan view of the proposed NDD facilities and twin tunnels is shown in Figure 1-1.

The BOR and DWR (Petitioners), have jointly petitioned the State Water Resources Control Board (State Board) for a Water Right Change Petition (Change Petition) through which they seek to add three new points of diversion in the north Delta on the Sacramento River between Collinsville and Courtland. The new North Delta Diversions (NDD) would allow up to 9,000 cfs to be diverted from this location.

2. Scenario Analysis

2.1 Introduction

The Petitioners have proposed four scenarios to reflect the potential range of operations that they foresee for the CWF project. The scenarios reflect a high to low range of diversions they would be able to export from the Delta as a result of the CWF project. The lowest and highest scenarios are presented as the upper and lower boundaries of what could be exported pursuant to the CWF. The four scenarios have been presented with a No Action Alternative, which, among other things, reflects the expected sea level rise and climate changes from global warming that are incorporated in the four project scenarios.

Although the two bounding scenarios represent the upper and lower range of potential exports, due to the complex nature of the hydrodynamics in the Delta, they don't necessarily reflect the upper and lower range of potential impacts to legal water users in the Delta. Some of those impacts to water users in the Delta will be described in the following sections.

In addition to the four proposed scenarios, Petitioners have acknowledged the many regulatory, environmental, and operational uncertainties associated with the proposed CWF project. Thus, Petitioners have indicated the need to adaptively manage the system. Petitioners have also acknowledged that because the various modeling scenarios do not actually reflect what is likely to happen in real time, the continued use of Temporary Urgency Change Petitions will be necessary.

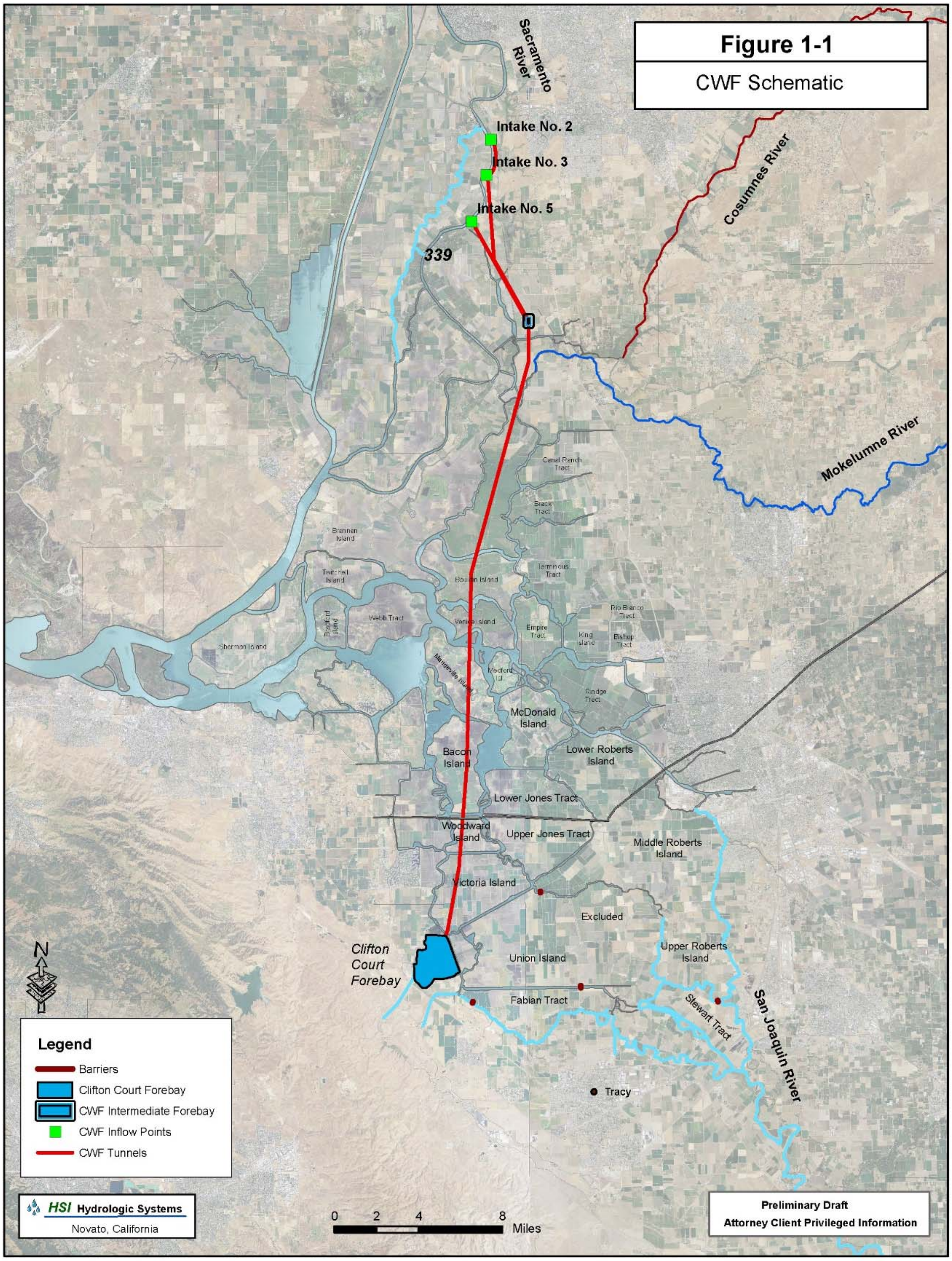


Figure 1-1
CWF Schematic
Sacramento River
Intake No. 2
Intake No. 3
Intake No. 5
339
Cosumnes River
Mokelumne River
McDonald Island
Bacon Island
Lower Roberts Island
Lower Jones Tract
Woodward Island
Upper Jones Tract
Middle Roberts Island
Victoria Island
Excluded
Clifton Court Forebay
Union Island
Upper Roberts Island
Fabian Tract
Stewart Tract
San Joaquin River
Tracy
Legend
Barriers
Clifton Court Forebay
CWF Intermediate Forebay
CWF Inflow Points
CWF Tunnels
HSI Hydrologic Systems
Novato, California
0 2 4 8 Miles
Preliminary Draft
Attorney Client Privileged Information

2.2 Water Fix Scenarios

The Petitioners have proposed four separate scenarios to describe the range of potential project exports to the SDD. The scenario have been developed as permutations of Alternative 4 from the DBCP Draft EIR.

The scenarios are implementations of Alternative 4A from the Bay Delta Conservation Plan/California WaterFix RDEIR/SDEIS. The actual CWF plan scenario implemented in any particular year will be determined by a decision tree as described in Scenario H of the Public Draft Bay Delta Conservation Plan EIR/EIS. Scenario H basically defines the spring and fall Delta outflow requirements, the Old and Middle River (OMR) outflow requirements, and the Head of Old River Barrier operations based on expected inflow to the Delta.

The details of the four scenarios are provided in the Draft EIR/EIS and CWF Hearing Exhibit DWR5. A summary of the scenarios is provided below.

1. NAA – No Action Alternative
    a. Includes Fall X2
    b. Delta Outflow Requirements Per D-1641
    c. NMFS SJR E/I Ratio
    d. OMR – Yes Per BiOps
    e. HOR – Temporary Barrier Installed In Fall Months

2. Boundary 1
    a. No Fall X2
    b. Outflow Requirements Per D-1641
    c. No NMFS SJR E/I Ratio
    d. OMR – Yes Per BiOps
    e. Permanent HOR Gate Operations in Fall Months Consistent With NAA

3. H3
    a. With Fall X2
    b. Outflow Requirements Per D-1641
    c. No NMFS SJR E/I Ratio
    d. OMR – BiOps or New RDEIR 4A Requirements
    e. Permanent HOR Gate Operations in Fall Winter and Spring (Partial Closure)

4. H4
    a. With Fall X2
    b. Outflow Requirements Per D-1641 Plus increased March – May Flows
    c. No NMFS SJR E/I Ratio
    d. OMR – BiOps or New RDEIR 4A Requirements
    e. Permanent HOR Gate Operations in Fall Winter and Spring (Partial Closure)

5. Boundary 2
    a. With Fall X2
    b. Per D-1641 and Increased Delta Outflow in All Months
    c. No NMFS SJR E/I Ratio
    d. OMR – BiOps or New RDEIR Appendix C Requirements
    e. Permanent HOR operating in Fall Winter and Spring (Full Closure)

There are two Export/Import rules that are presently in place. The Delta E/I ratio and the San Joaquin River E/I ratio. The Petitioners have changed the definition of the Delta E/I ratio to not include the NDD as an export, and the Sacramento River inflow will be measured downstream of the NDD. This is with the exception of H4 which will have the Sacramento River flow measured upstream of the NDD. The NMFS San Joaquin River Inflow/Export ratio appears to be removed from the four project scenarios.

2.3 Regulatory Requirements

There are various regulatory requirements that apply to the export of flows from the Delta. The primary regulations that apply to the Delta are The "Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary" (Basin Plan), Water Right Decision D-1641, which implements portions of the Basin Plan, and various fisheries requirements from the National Marine Fisheries Services (NMFS), the U.S. Fish and Wildlife Service (USFWS), and the California Department of Fish and Wildlife (DFW). The main requirements that effect water quality in the Central and South Delta are contained within D-1641. D-1641 establishes water quality objectives at locations throughout the Delta. Figure 2-1 is a map showing the locations where water quality objectives have been set.

The salinity objectives for the central and south Delta are primarily represented by three compliance points, Old River at Tracy Road Bridge, Old River at Middle River, and San Joaquin River at Brandt Bridge. Although these are the locations where compliance is being measured, the 2006 WQCP specified that the water quality requirements need to be met throughout the channel.

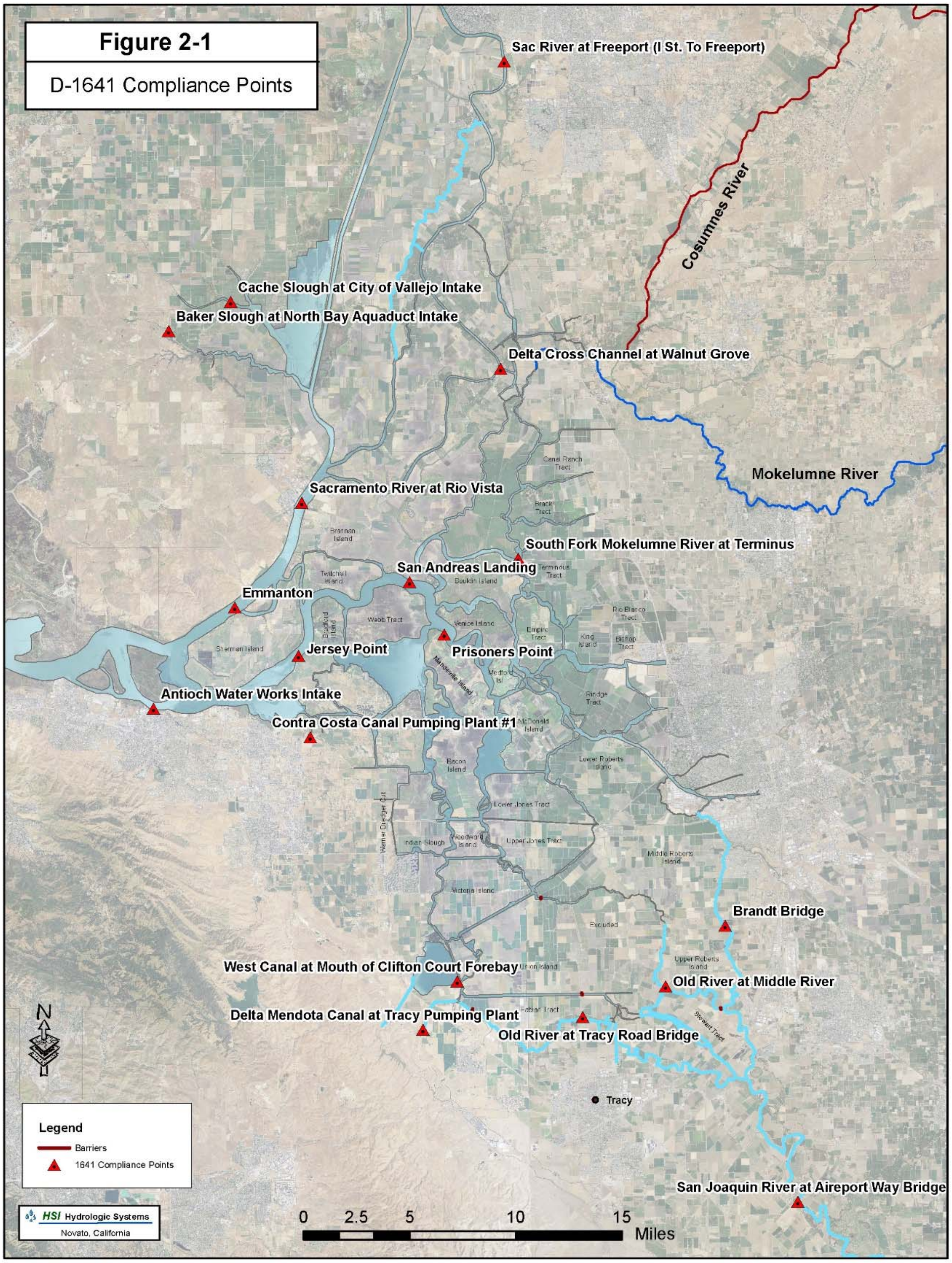


Figure 2-1
D-1641 Compliance Points
Sac River at Freeport (I St. To Freeport)
Cosumnes River
Cache Slough at City of Vallejo Intake
Baker Slough at North Bay Aquaduct Intake
Delta Cross Channel at Walnut Grove
Mokelumne River
Sacramento River at Rio Vista
South Fork Mokelumne River at Terminus
San Andreas Landing
Emmanton
Jersey Point
Prisoners Point
Antioch Water Works Intake
Contra Costa Canal Pumping Plant #1
Brandt Bridge
West Canal at Mouth of Clifton Court Forebay
Old River at Middle River
Delta Mendota Canal at Tracy Pumping Plant
Old River at Tracy Road Bridge
Tracy
San Joaquin River at Aireport Way Bridge
Legend
Barriers
1641 Compliance Points
HSI Hydrologic Systems
Novato, California
0 2.5 5 10 15
Miles

The compliance points are an attempt to find locations that can represent the whole channel. The D-1641 objectives are not being met at these locations on many years. Changes to the Delta flow patterns by the CWF scenarios will result in higher salinities approximately 50% of the time, thus increasing the amount of time that the projects will be out of compliance with the regulations. An analysis of the Electrical Conductivity (EC) from the Petitioners DSM2 models show an often significant increase in EC for some of the proposed scenarios. Those results will be described in Section 4.1.

2.4 Existing Conditions of Concern

Three important concerns in the central and south Delta are salinity, water stage, and algal blooms. The salinity can affect the farmers in the Delta and their ability to grow crops. The existing salinity in the Delta is highly variable and typically increases during periods of low inflow and during droughts. Salinity can be effected by changing the flow patterns in the Delta so that 1)the flushing rate of existing Delta water increased or decreased, and 2), the amount of fresh water entering the Delta is reduced. The CWF scenarios tend to do both. Figure 2-2 is a plot of the existing salinity level at the Old River at Tracy Gage. As can be seen in the figure, the existing salinity exceeds the D-1641 requirements for a significant period of time. Any changes to the Delta that result in an increase in salinity Old River, will increase the amount of time that the project is in non-compliance with D-1641.

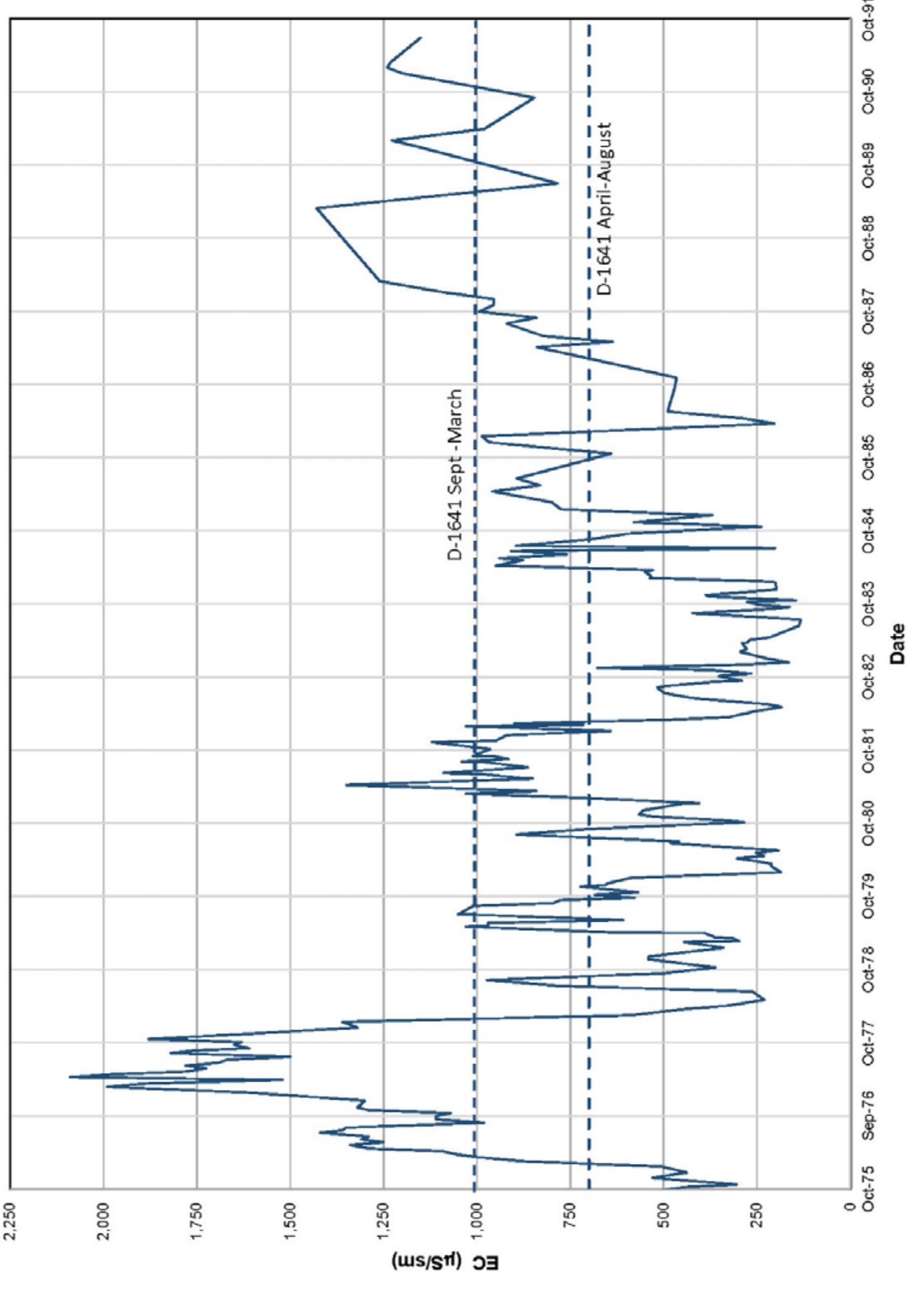
Algal blooms in the Delta have become an increasing concern over the past few years. The growth of algae has numerous water quality effects. As the algae grow, they respirate, producing oxygen during the day, but also absorbing oxygen during the night. This can result in diurnal oxygen swings when the algae are growing. The process of photosynthesis also results in a change pH of the water, which can affect the local fish. After a period of growth, the algae tend to die-off, producing a mass of detritus that as it decays can remove a significant amount of oxygen from the water. The dead algae mass then provides a significant source of phosphorus, a necessary nutrient for growth, for the next bloom-and-crash algal cycle.

The appearance of Microcystis cyanobacteria in the algal population also presents a significant health risk to animals that may drink the water. Cyanobacteria can produce neurotoxins that are poisonous and destructive to nerve tissue.

Factors effecting algal growth include residence time, which allows the water a longer period to heat up resulting in an increase in algal growth. Residence time also slows down the flushing action of the Delta which helps to remove nutrients and existing algae in the system. Details of how the CWF scenarios decrease flushing flows through the system are described in Section 4.4.

Exhibit SDWA-47

Figure 2-2 Measured Salinity At Old River at Tracy and The D-1641 Compliance Targets



3. Modeling Process

3.1 CALSIM II

The CALSIM II model was used to evaluate the different scenarios for the CWF project. The model is basically an operations model that evaluates inflow to the system, system storage, and export and demand requirements of the system, which includes the Delta. The model has several Artificial Neural Networks that provides some relationships between flow and water quality characteristics in the Delta. The model, although used almost exclusively for the CVP and SWP operations, has had no extensive calibration or sensitivity analysis. A limited study was conducted in 2005, but there have been no evaluations conducted of the recent versions of CALSIM II used in the Petitioners study.

The CALSIM II analysis was conducted over an 82 year period, ending in 2003. It would have been very helpful and informative if the model had been run including the most recent period through 2015 that includes the latest drought period.

3.2 DSM2

The DSM2 model is a 1-dimensions unsteady flow model that is used to evaluate hydrodynamics and water quality through the Delta. The model domain reaches the Delta, extending from Sacramento to Vernalis, and the western Delta to Antioch. The input to DSM2 comes from the CALSIM II model. The DSM2 model was used to evaluate the effect of the CWF scenarios on the hydraulics and water quality in the Delta. The DSM2 model was run for a 16 year period from Water Year (WY) 1976 to Water Year 1991. An additional year was added to the beginning of the model period to give the model time to come to equilibrium with the system. Therefore, that first year (WY 1975) cannot be use in the analysis.

Given that the CALSIM II model produces the input to the DSM2 model it is unknown why a more complete and longer period of record was not used. The 16 year period from 1976 to 1991 has some similarities to the 82 year period of record used in CALSIM II, but deviates considerable when focusing on wet and dry years. This is especially important when the Petitioners use the DSM2 output to develop exceedance analyses for stage, flow, and salinity, like was done in the Petitioners CWF modeling exhibits.

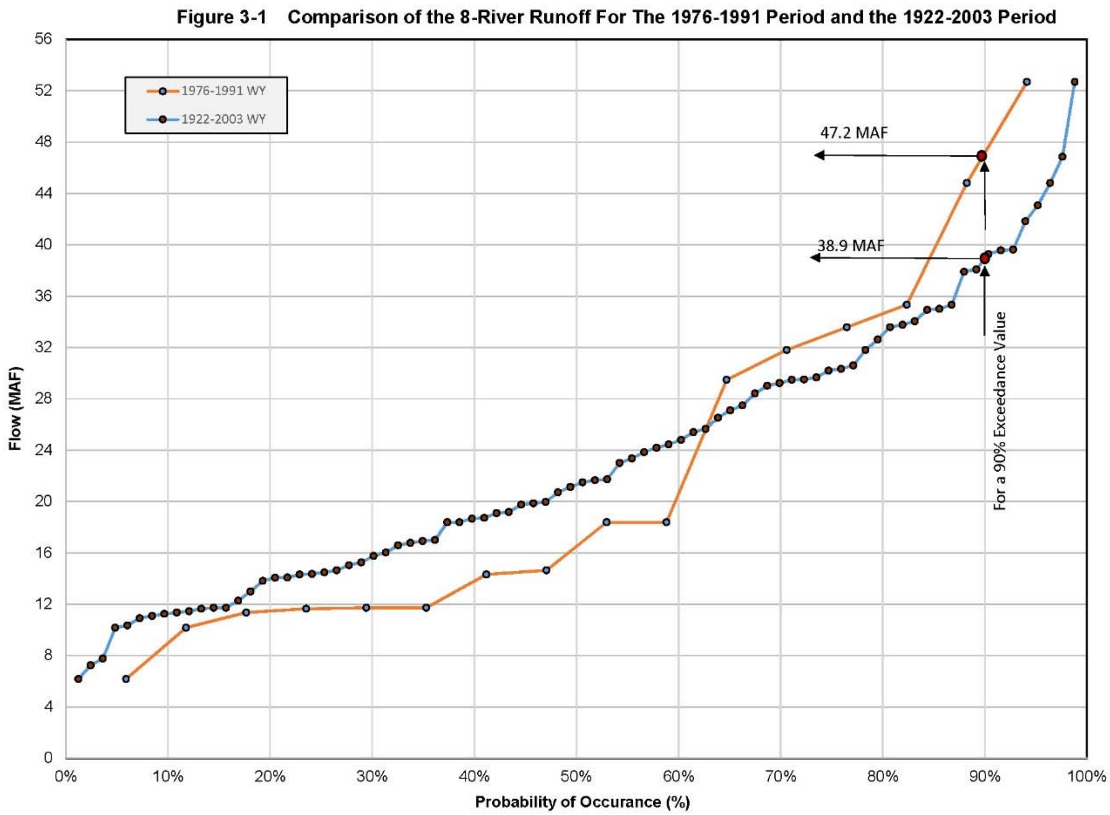
The difference in the hydrologic characteristics represented by the two periods can be measured by looking at the DWR 8-River unimpaired runoff. That annual runoff data can be found on the California Data Exchange Center (CDEC). The data is provided annually from 1906 to 2015. If you perform an exceedance analysis on the runoff over the 82 year period of record that was used in the CALSIM II model, you will get a set of exceedance probabilities as shown in column 2 of Table 3-1. If one performs an exceedance analysis on the 8-River Index for just the 1976-1991 period, one will get a different set of expected flows as shown in column 3 of Table 3-1. The fourth column shows the difference in the expected runoff between the two periods. As can be seen in the Table using the shorter 16 year period, one would be under predicting runoff from dry periods by 20% and over predicting high flows by 21%. A probability plot comparing the two different time periods is shown in Figure 3-1. This example is not to mean that DSM2 is used to predict runoff, this is only an illustration to show that the two periods represent different hydrologic condition. Therefore, any probability or exceedance analysis that is performed using the results of the DSM2 model would be incorrect and unreliable.

Table 3-1 Difference in Exceedance Probabilities Between The 1996 Through 1991 Period and The 1922 through 2003 Period

Probability of Exceeding Specified Flow	1922-2003, 82 Year Period	1976-1991 16 Year Period	% Difference
(%)	(MAF)	(MAF)	(%)
10	11.3	9.0	20.4%
20	14.0	11.5	17.9%
30	15.7	11.7	25.5%
40	18.7	13.8	26.1%
50	21.3	16.5	22.5%
60	24.7	20.6	16.7%
70	29.3	31.6	-7.9%
80	33.0	34.6	-4.9%
90	38.9	47.2	-21.3%
95	42.9	52.7	-22.9%

3.3 Model Reliability

Both the CALSIM II model and the DSM2 model were modified for the analysis of the CWF scenarios. In order to have confidence in a model, the model needs to undergo extensive calibration, verification, and sensitivity analyses. These important steps have not been conducted on the latest incarnations of the models that reflect the CWF elements.



4. Impact Analysis

4.1 Introduction

The Petitioners have proposed four scenarios to represent the potential operations of the CWF Project- The details of the four scenarios are summarized in Section 2.2 herein. The scenarios have been developed to provide a range of potential exports for the state and federal projects. This range, bracketed by the two scenarios B1, high exports, and B2, low exports, would reduce the volume and quality of water that enters and flows through the Delta. The scenarios involve removing fresh water from the Sacramento River through the North Delta Diversions and bypass this water around the Delta through 2 parallel tunnels. The downstream end of the tunnels will discharge into Clifton Court Forebay. A plan view of the bypass scheme is provided in Figure 1-1.

This section evaluates the impact that removal of water through the NDD's will have on the legal users of water in the Delta. We conducted an evaluation of water quality, river stage, and flushing analysis for each of the four scenarios. The impacts were evaluated by comparing the change in conditions for each scenario to the No Action Alternative (NAA.) This approach is a way to isolate and evaluate just those changes that were incorporated in each scenario.

4.2 Analysis of Salinity Changes

A detailed analysis of the salinity changes that would result from the four CWF Scenarios was conducted. The salinity changes for each of the scenarios were evaluated at 17 locations throughout the Delta using the Petitioners DSM2 models. Those locations are shown in Table 4-1 and Figures 4-1 through 4-3 herein.

An analysis was also conducted to determine the effects the CWF Scenarios would have on the salinity at specific locations in the Central and South Delta. The analysis presented by the Petitioners has been based on an analysis of mean monthly salinity data. This monthly analysis of salinity, especially when averaged over multiple years, appears to show that there are minor changes in salinity levels resulting from for the 4 different CWF scenarios as compared to the NAA. The minor changes shown by the Petitioners is really an artifact of how they averaged the numbers together. By averaging the 15-minute data into daily, then daily into monthly, and monthly into mean monthly or annual values, they mask the true variability of the salinity results at each location. Averaging over large time scales is not an appropriate when evaluating the changes in salinity.

This type of averaging approach used by Petitioners might, arguably be appropriate to a water supply analysis where deficits in one-month might may be balanced by a surplus the following month. However, where negative impacts are experienced at the specific time that the deficit occurs, averaging will mask the actual effects resulting from a given alternative, or, in this case, the four CWF scenarios. The impacts to crops resulting from the increase in salinity over the daily or weekly timeframe will be addressed by Terry Prichard who will be testifying on behalf of SDWA.

Table 4-1 Detailed Analysis Locations

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
10	SDN10	Emmanton	434
11	DB1	Indian Slough at Old River	236
12	DB2	Indian Slough	237
13	DB3	Indian Slough at Discovery Bay	238
15	DB4	Warner Dredger Cut	239
16	DB5	Old River Upstream of Indian Slough	92
17	DB6	Old River Down Stream of Indian Slough	94

To demonstrate the inappropriate use of averaging to determine whether injury results to other legal users of water, one can simply compare the result of Petitioner's averaging approach with an analysis of the results on a daily and weekly basis The change in salinity at the Old River at Tracy Road gage site was evaluated on a 15-minute, Daily, Monthly, and Mean Monthly period. The results from each of the time periods was compared to the NAA, which was calculated for the same periods.

To determine the daily salinity values for each of the above referenced sites, the DSM2 models for the 4 CWF scenarios and NAA were run for the 1976 through 1991 water years (16 years). The DSM2 model computes the flow and water quality characteristics on a 15-minute time step throughout the Delta. The 15-minute output data from the model were averaged to produce a daily mean of salinity at each location. A plot of the time series of the computed daily EC for each site and each CWF scenario is provided in Exhibit SDWA-49. Excerpts from this analysis were used during cross-examination of the DWR and USBR modeling panel as Exhibit SDWA-29 and SDWA-30, but the full data sets from the analysis are provided in Exhibits SDWA-52 and SDWA-53, which are Excel spreadsheets containing the DSM2 model output.


Figure 4-1
Detailed Analysis Points
Sheet 1 of 3
Middle River near Howard Road Bridge
San Joaquin River at Brant Bridge
San Joaquin River 1
San Joaquin River
Upper Roberts Island
Middle River at Head
Stewart Tract
Middle River
Grant Line Canal, Upstream
Tom Paine Slough
Excluded
Old River at Tracy
Old River
Grant Line Canal
Old River 1
Union Island
Fabian Tract
0 0.5 1 2 3 4 Miles
N
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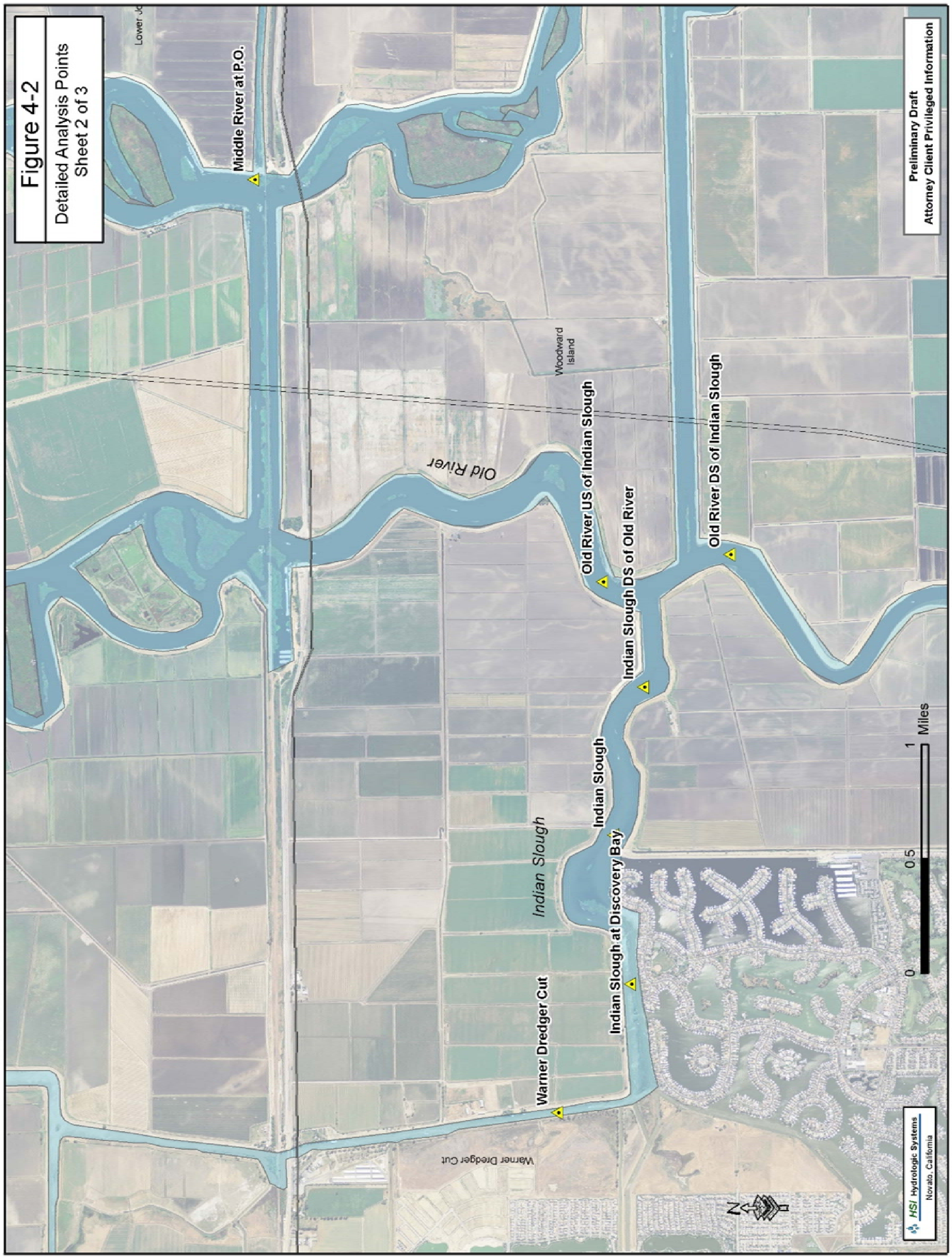

Figure 4-2
Detailed Analysis Points
Sheet 2 of 3
Middle River at P.O.
Old River
Woodward Island
Old River US of Indian Slough
Indian Slough DS of Old River
Old River DS of Indian Slough
Indian Slough
Indian Slough
Indian Slough at Discovery Bay
Warner Dredger Cut
Warner Dredger Cut
0
0.5
1
Miles
N
HSI Hydrologic Systems
Novato, California
Preliminary Draft
Attorney Client Privileged Information

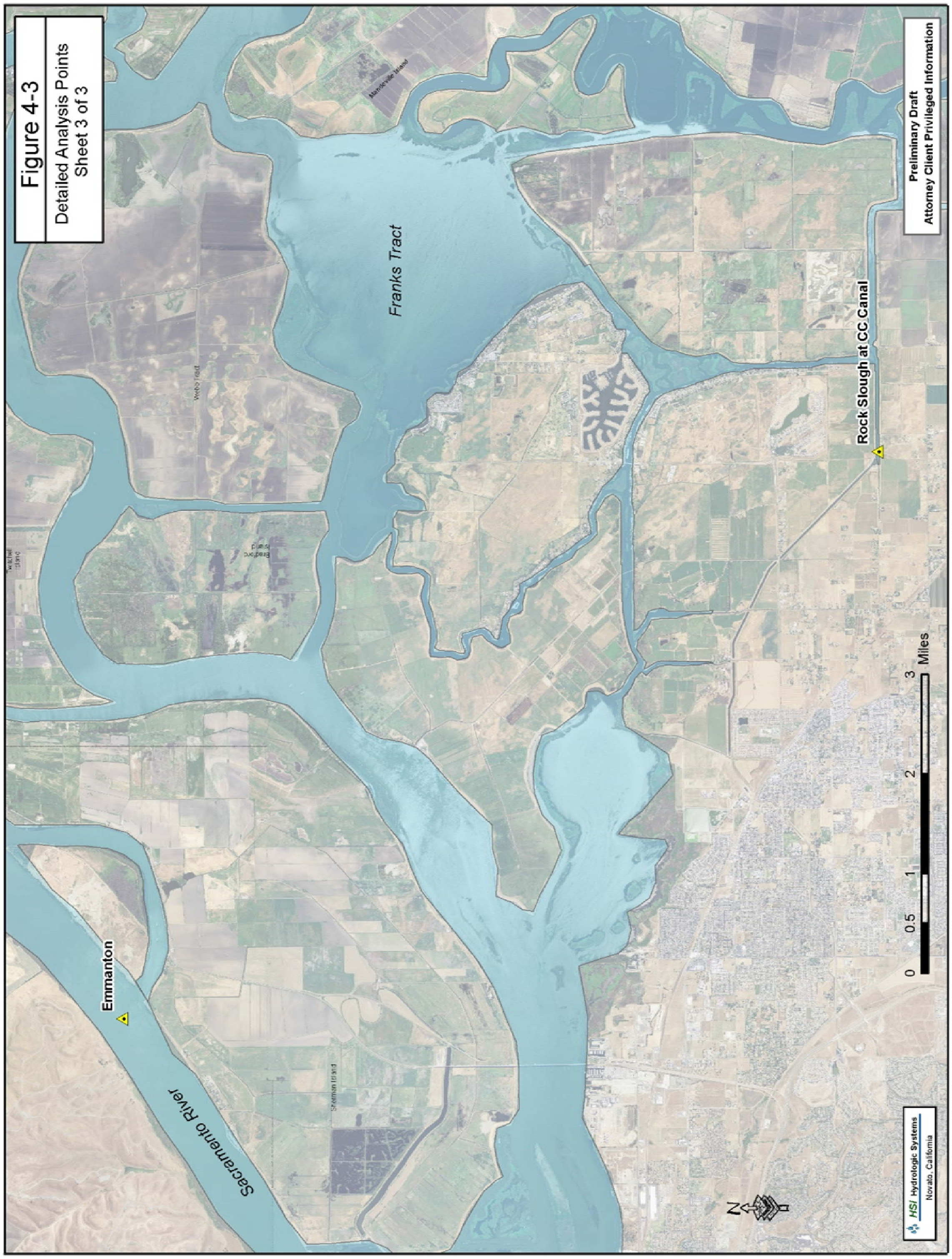
Figure 4-3
Detailed Analysis Points
Sheet 3 of 3
Franks Tract
Rock Slough at CC Canal
Emmanton
Sacramento River
0 0.5 1 2 3 Miles
Preliminary Draft
Attorney Client Privileged Information
HSI Hydrologic Systems
Novato, California

Figure EC5 in DWR Exhibit 513 is an example of how changes in salinity were evaluated by the Petitioners. For reference, Petitioners' figure EC5 from DWR Exhibit 513 is provided in Figure 4-4. To develop this figure, the Petitioners computed the 15-minute values from DSM2, the 15-minute values were then averaged to provide a daily value, the daily values were subsequently averaged to provide a monthly value, and finally the monthly values were averaged over the 16-year period of record to produce a mean monthly value for each month. As can be seen in the figure, except for the months of April and May, there does not appear to be significant difference in the salinity levels resulting from the 4 different CWF scenarios as compared to that of the NAA. The Petitioners averaged the highs and lows of the original salinity computation down to a seemingly negligible amount.

A more appropriate way of analyzing the change in salinity resulting from the CWF scenarios is to measure the results relative to the actual time frames and durations when injury could occur. For applied irrigation, the appropriate time frame is daily, and at most weekly. A monthly, or mean monthly analysis averaged over many years, is simply inappropriate when considering the potential injury to agricultural production from a potential increase in salinity.

The actual daily differences in salinity levels resulting from the CWF Scenarios as compared to the NAA are significant. There are numerous locations where the salinity levels on a daily and weekly basis resulting from the CWF scenarios are significantly greater than the NAA. The method of analysis used by Petitioners masks these impacts.

The daily differences between each of the CWF scenarios and the NAA was computed for each site over the 1976 through 1991 time period that was used in the Petitioners DSM2 model. Figure 4-5 is a plot of the daily salinity difference between the B1 and B2 scenarios and the NAA for the Old River at Tracy. As you can see by the plot, there are numerous instances where the salinity of the CWF scenario is significantly greater than the NAA. In several instances the CWF scenario is 400 to 600 μS/cm higher than the NAA. Figure 4-6 shows the same information, except on an annual basis. The difference in salinity is less than the comparison on a daily basis, but you can see that the salinity is higher in the CWF scenarios over that of the NAA in most years. Daily salinity difference plots for all of the sites that were evaluated are provided in Exhibit SDWA-50.

The percentage of time that the salinity for each CWF scenario is above that of the NAA was also calculated over the 16 year period of the DSM2 model. The salinity for the CWF scenarios is higher than the NAA roughly 50% of the time, but can be as high as 91% during dry years. The percentage of time that the salinity for the CWF scenarios are higher than the NAA for the Old River at Tracy site is shown in Table 4-2. Figure 4-6b is a plot of the percent of time that the CWF scenarios have a higher salinity than the NAA on a daily basis.

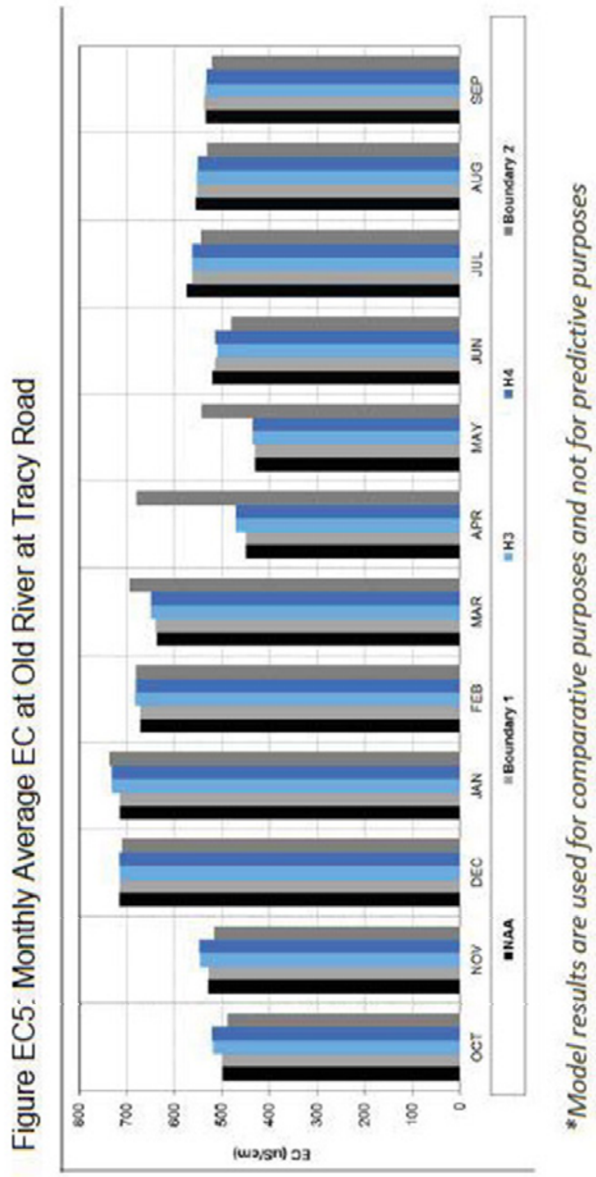

Figure 4-4
From DWR Exhibit 513, Figure EC5

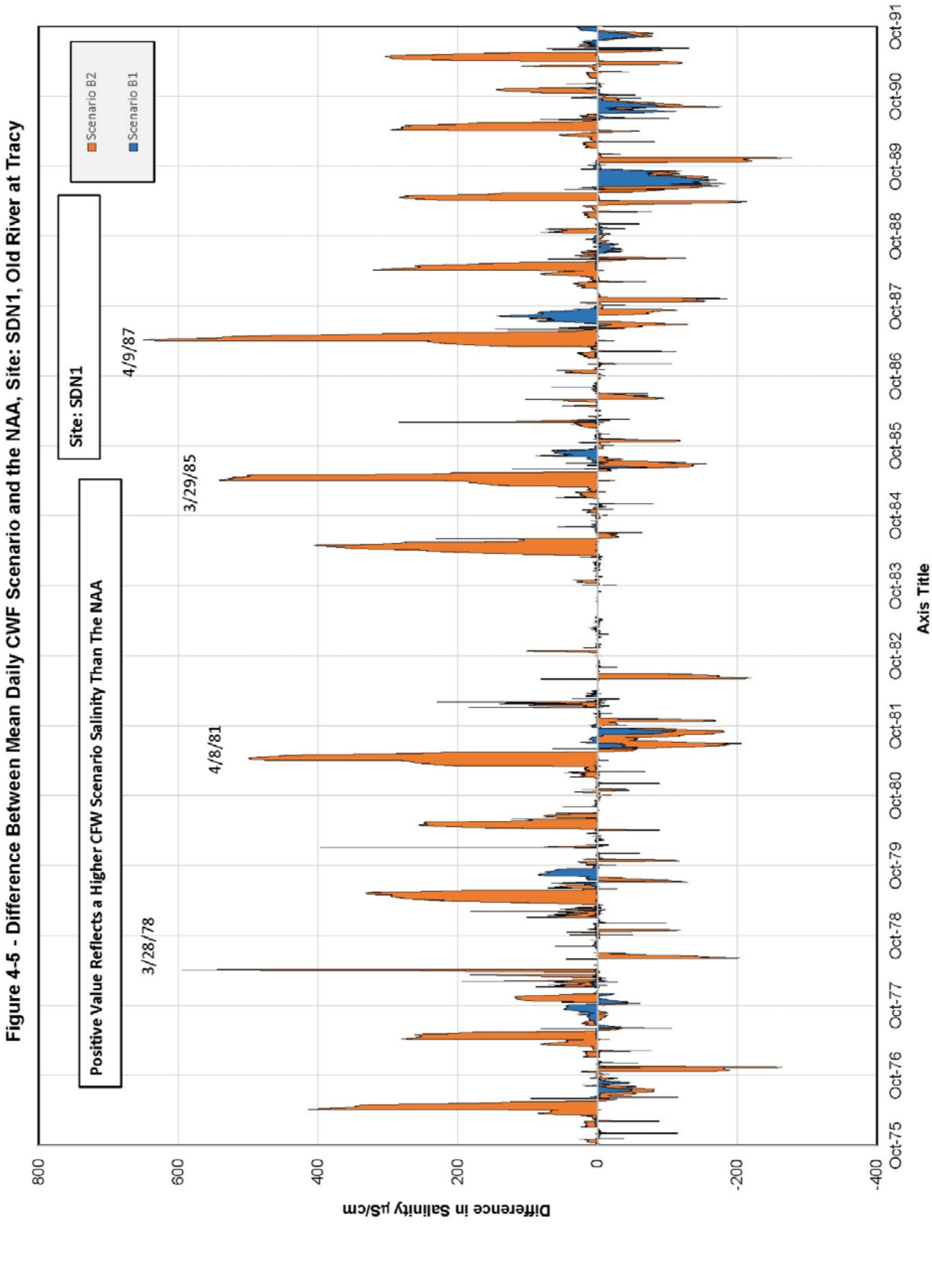
Figure 4-5 - Difference Between Mean Daily CWF Scenario and the NAA, Site: SDN1, Old River at Tracy
Positive Value Reflects a Higher CFW Scenario Salinity Than The NAA
Site: SDN1
Scenario B2
Scenario B1
3/28/78
4/8/81
3/29/85
4/9/87
Difference in Salinity µS/cm
800
600
400
200
0
-200
-400
Oct-75
Oct-76
Oct-77
Oct-78
Oct-79
Oct-80
Oct-81
Oct-82
Oct-83
Oct-84
Oct-85
Oct-86
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Oct-90
Oct-91
Axis Title

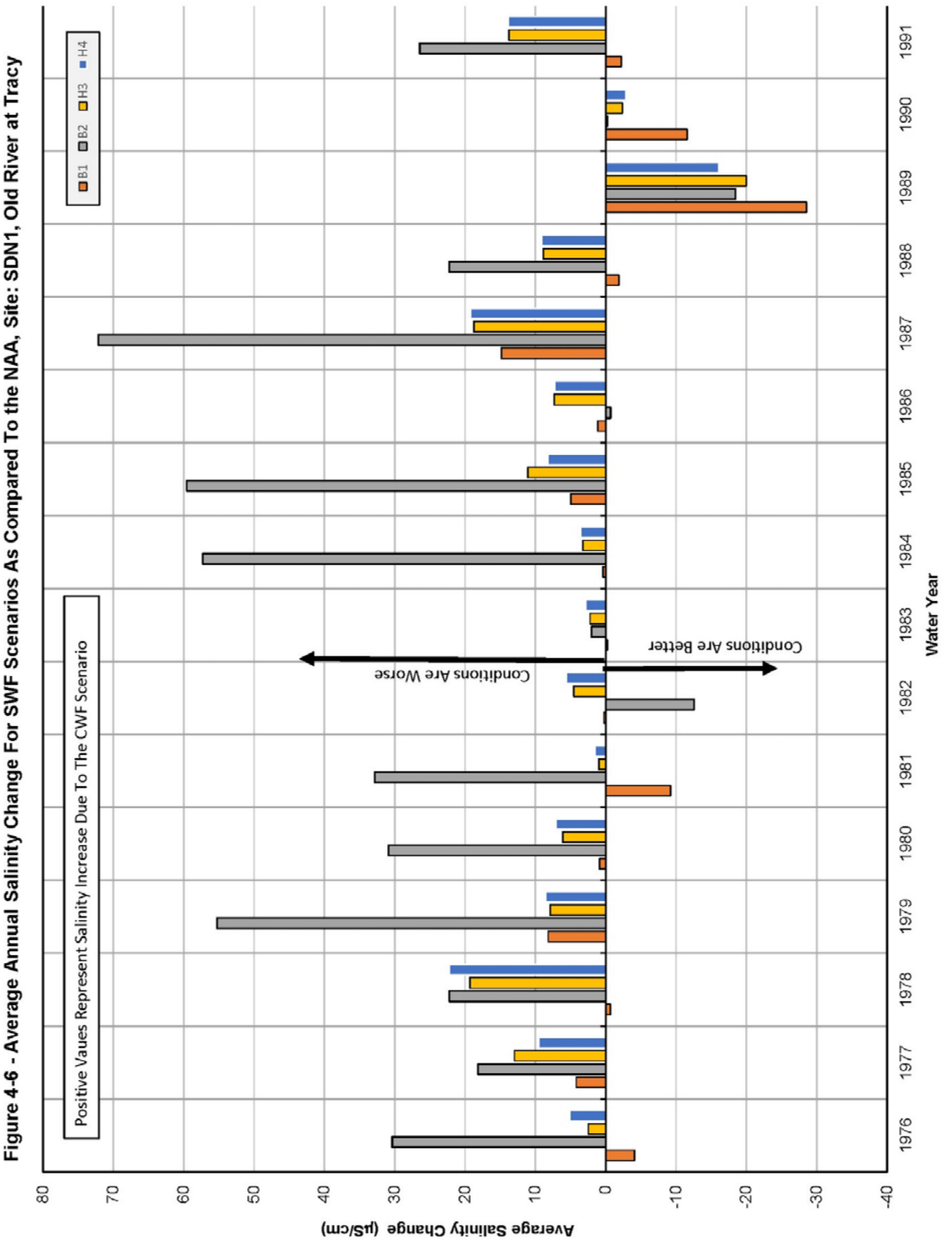


Figure 4-6 - Average Annual Salinity Change For SWF Scenarios As Compared To the NAA, Site: SDN1, Old River at Tracy
Positive Vaues Represent Salinity Increase Due To The CWF Scenario
B1
B2
H3
H4
Conditions Are Worse
Conditions Are Better
Average Salinity Change (µS/cm)
Water Year
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991

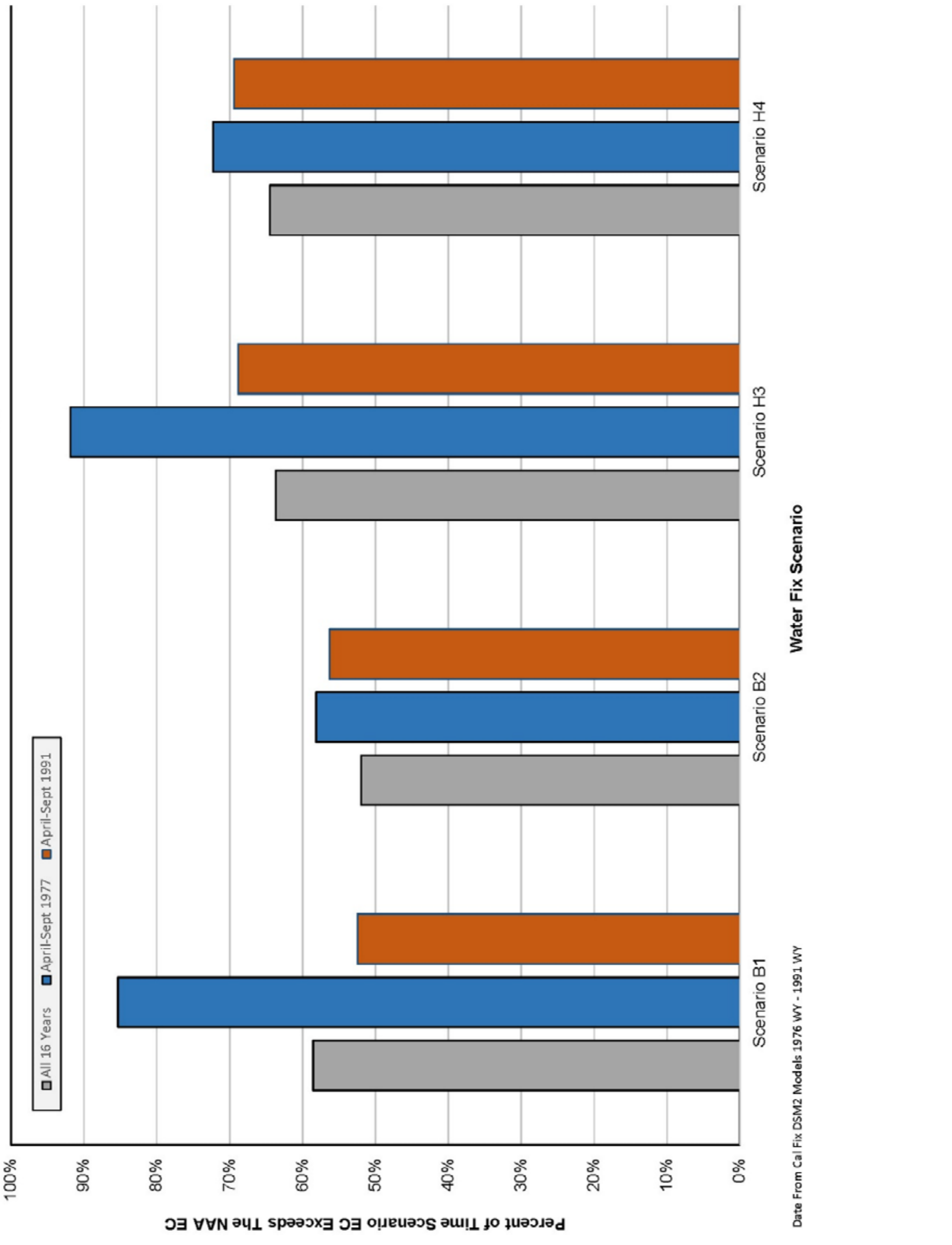


Figure 4-6b - The Amount of Time the Daily Average EC of the Water Fix Scenarios Exceeds the EC of the NAA Location: Old River at Tracy, SDN1

This same information for the other sites identified in Table 4-1 are provided in Table 4-3. Exhibit SWDA-50 shows the difference in salinity between the CWF scenarios and the NAA on a daily and annual basis for each of the sites listed in Table 4-1. Plots showing the percent of time that the CWF scenario is higher than the NAA for the other sites listed in Table 4-1 are provided in Exhibit SDWA-51.

As can be seen in the daily salinity difference plots in that are in Exhibit SDWA-50, the increase in salinity of the CWF scenario over the NAA can be significantly higher during portions of the year. As one example, Table 4-4 lists the maximum increase in salinity at the Old River at Tracy site. As can be seen in the table, the salinity for scenario B2 can be as high as 650 μS/cm over the NAA condition.

TABLE 4-2 Amount of Time That The CWF Scenarios Have a Higher Salinity Than The NAA at The Old River at Tracy Site, Based on the Daily EC Average.

Period	CFW Scenario			
	B1	B2	H3	H4
WY 1976 - 1991	58.6%	52.0%	63.7%	64.5%
Summer 1977	85.3%	58.2%	91.8%	72.3%
Summer 1991	52.5%	56.3%	68.9%	69.4%

Table 4-3 - Evaluation of Amount of Time That The Daily Mean EC For Each Of The CWF Scenarios Is Higher Than The NAA Scenario

DB1 - Indian Slough US of Discovery Bay

	B1	B2	H3	H4
WY 1976 - 1991	51.7%	47.9%	48.5%	48.5%
Summer 1977:	64.7%	54.3%	89.7%	71.2%
Summer 1991:	38.8%	25.1%	39.3%	39.3%

DB2 - Indian Slough US of Discovery Bay

	B1	B2	H3	H4
WY 1976 - 1991	51.1%	47.1%	45.8%	45.8%
Summer 1977:	65.2%	38.0%	88.6%	67.4%
Summer 1991:	35.0%	18.0%	30.1%	30.6%

DB3 - Indian Slough at Discovery Bay

	B1	B2	H3	H4
WY 1976 - 1991	50.4%	46.2%	44.6%	44.7%
Summer 1977:	65.2%	35.9%	87.5%	65.2%
Summer 1991:	33.3%	18.0%	29.5%	29.5%

DB4 - Warner Dredger Cut DS of Discovery Bay

	B1	B2	H3	H4
WY 1976 - 1991	51.4%	46.2%	44.9%	45.1%
Summer 1977:	62.5%	33.7%	83.2%	61.4%
Summer 1991:	36.1%	18.0%	34.4%	35.0%

DB5 - Old River US of Indian Slough

	B1	B2	H3	H4
WY 1976 - 1991	54.0%	48.9%	51.4%	51.5%
Summer 1977:	64.7%	65.2%	89.1%	71.7%
Summer 1991:	43.7%	32.2%	42.1%	43.2%

DB6 - Old River DS of Indian Slough

	B1	B2	H3	H4
WY 1976 - 1991	54.1%	48.3%	50.5%	50.5%
Summer 1977:	64.7%	64.1%	89.1%	71.2%
Summer 1991:	43.2%	31.7%	41.5%	42.1%

SDN1 - Old River at Tracy

	B1	B2	H3	H4
WY 1976 - 1991	58.6%	52.0%	63.7%	64.5%
Summer 1977:	85.3%	58.2%	91.8%	72.3%
Summer 1991:	52.5%	56.3%	68.9%	69.4%

SDN2 - Old River 1

	B1	B2	H3	H4
WY 1976 - 1991	54.5%	49.3%	62.8%	62.8%
Summer 1977:	70.1%	51.1%	94.0%	72.8%
Summer 1991:	37.2%	57.9%	69.9%	69.9%

Table 4-3 - Evaluation of Amount of Time That The Daily Mean EC For Each Of The CWF Scenarios Is Higher Than The NAA Scenario

SDN3 - Grant Line Canal

	B1	B2	H3	H4
WY 1976 - 1991	66.9%	48.8%	70.2%	68.7%
Summer 1977:	90.8%	38.6%	78.8%	48.9%
Summer 1991:	32.2%	20.2%	37.2%	37.2%

SDN4 - Middle River at Head of Grant Line Canal

	B1	B2	H3	H4
WY 1976 - 1991	73.2%	52.3%	72.1%	71.8%
Summer 1977:	67.4%	54.3%	44.0%	58.2%
Summer 1991:	81.4%	27.3%	66.7%	50.3%

SDN5 - Middle River near Howard Road Bridge

	B1	B2	H3	H4
WY 1976 - 1991	48.4%	45.5%	54.1%	53.7%
Summer 1977:	62.5%	53.3%	66.8%	60.9%
Summer 1991:	62.3%	62.3%	59.6%	59.6%

SDN6 - Middle River at P.O.

	B1	B2	H3	H4
WY 1976 - 1991	56.2%	54.9%	59.5%	59.5%
Summer 1977:	58.2%	77.7%	100.0%	82.6%
Summer 1991:	49.2%	76.5%	65.0%	65.6%

SDN7 - Tom Paine Slough

	B1	B2	H3	H4
WY 1976 - 1991	51.8%	47.9%	58.5%	60.4%
Summer 1977:	87.0%	34.2%	83.2%	63.0%
Summer 1991:	38.3%	23.0%	41.5%	42.6%

SDN8 - San Joaquin River 1

	B1	B2	H3	H4
WY 1976 - 1991	67.2%	16.4%	42.5%	40.3%
Summer 1977:	67.9%	33.2%	41.8%	35.9%
Summer 1991:	95.1%	0.5%	61.7%	47.5%

SDN9 - San Joaquin River at Brandt Bridge

	B1	B2	H3	H4
WY 1976 - 1991	62.9%	17.1%	35.8%	34.9%
Summer 1977:	87.0%	32.6%	44.6%	33.7%
Summer 1991:	89.1%	12.6%	52.5%	39.3%

SDN10 - Emmanton

	B1	B2	H3	H4
WY 1976 - 1991	87.4%	48.6%	69.5%	64.4%
Summer 1977:	53.8%	21.7%	69.6%	33.2%
Summer 1991:	100.0%	88.0%	100.0%	100.0%

Table 4-3 - Evaluation of Amount of Time That The Daily Mean EC For Each Of The CWF Scenarios Is Higher Than The NAA Scenario

Average of All Sites:

	B1	B2	H3	H4
WY 1976 - 1991	59%	45%	55%	54%
Summer 1977:	70%	47%	78%	61%
Summer 1991:	54%	35%	52%	50%

Max of All Sites:

	B1	B2	H3	H4
WY 1976 - 1991	87%	55%	72%	72%
Summer 1977:	91%	78%	100%	83%
Summer 1991:	100%	88%	100%	100%

Min of All Sites:

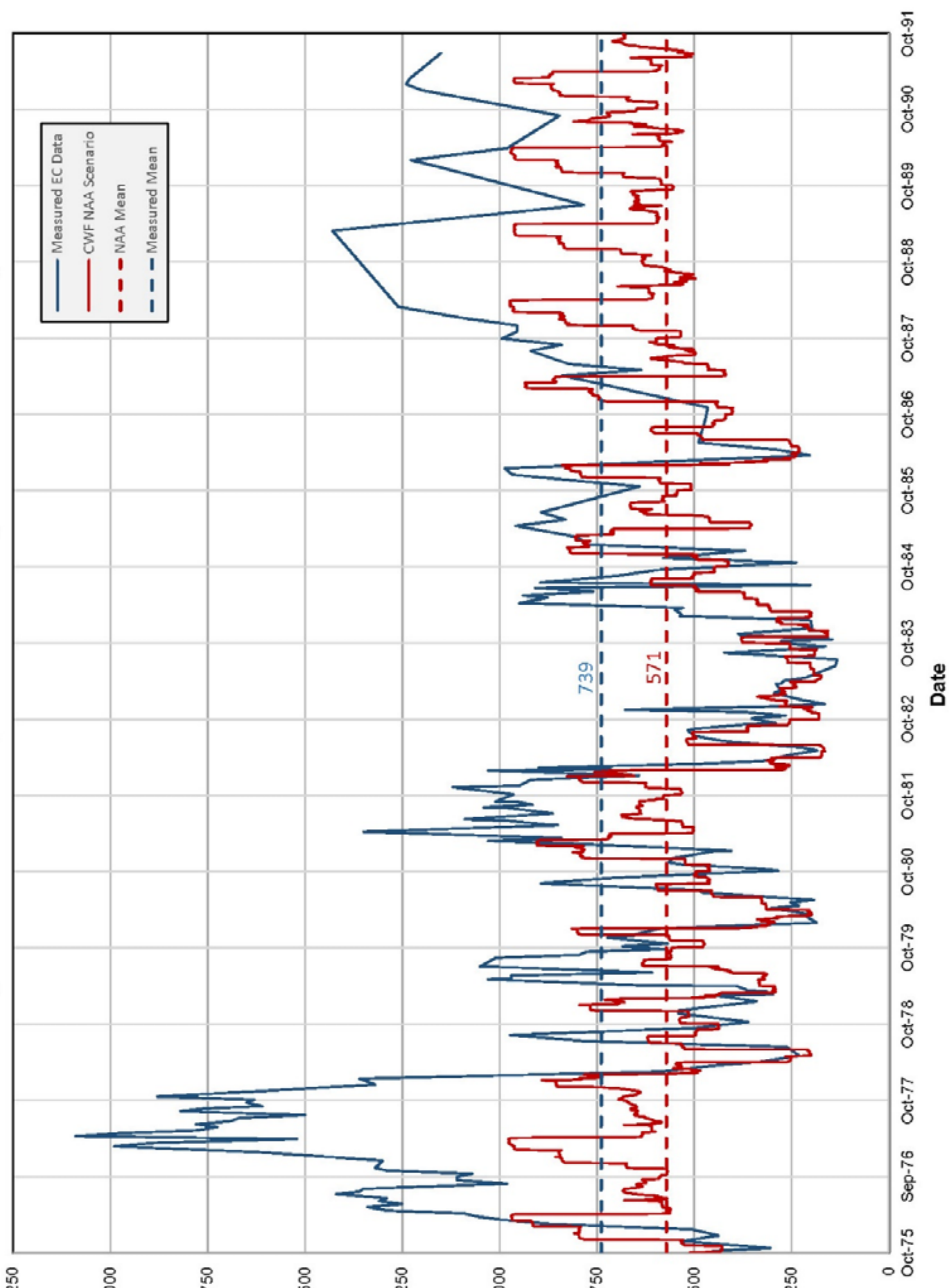
	B1	B2	H3	H4
WY 1976 - 1991	48%	16%	36%	35%
Summer 1977:	54%	22%	42%	33%
Summer 1991:	32%	1%	30%	30%

Table 4-4 Maximum Increase in Salinity For The 4 CWF Scenarios over The NAA At The Old River At Tracy Gage Site (WY 1976-1991)			
B1	**B2**	**H3**	**H4**
(μS/cm)	(μS/cm)	(μS/cm)	(μS/cm)
144	650	363	363

In the calculation of salinity in the South Delta, the DSM2 model cannot accurately predict the actual salinity even when using known historical inputs to the model. The model sometimes over-predicts the salinity and sometimes under-predicts the salinity. The cause for this instability of prediction has yet to be understood. Therefore, we cannot be sure that the model response to the changes from one scenario to another is accurate and, therefore, reflects the dynamics of the system and the nature of the impacts resulting from each CWF scenario. Figure 4-7 is a plot of the actual measured EC values and the DSM2 predicted EC at the Old River at Tracy site for the NAA. As can be seen by the graph, at this location, the DSM2 model is grossly under predicting the EC through much of the 16 year period. Therefore, comparison of the model results at this site, to the D-1641 objectives would be inappropriate and misleading. This is especially true considering that this is a location where DWR is already not meeting the requirements of D-1641.

It should be further noted, that the NAA alternative as plotted in Figure 4-7, includes the 15cm sea level rise and the global warming changes in the input hydrology to the system. Yet, with these changes, which would tend to increase salinity in the Delta, the model still significantly under predicts the measured salinity at Old River at Tracy, which does not include sea level rise or global warming. This would tend to indicate that the error within the DSM2 model has a greater impact on the model output for salinity in the south Delta than the effects of both sea level rise and global warming combined. This model inaccuracy may also have a greater effect on the model output than the differences within the 4 different scenarios, making a comparison of the scenarios unreliable and potentially inaccurate.

Figure 4-7 Measured Salinity At Old River at Tracy and The Predicted Salinity from The NAA



4.3 Analysis of Changes in Water Level

The NDD's will divert up to 9,000 cfs during portions of some years. This large of a diversion can impact the water level in the river downstream of the diversion. An analysis was conducted to determine the change in water level at several locations downstream of the NDD point of withdrawal. The water level for each CWF scenario was compared to the NAA at 3 locations. The first was immediately downstream of the NDD, the second was 3 miles downstream of the NDD, and the third was 9 miles downstream of the NDD.

The results of the analysis showed a variable reduction in the water level change depending on the time of year. Table 4-5 shows the maximum and average reduction in water level for the 16 year period that was modeled by the Petitioner's DSM2 model. There are periods when the difference in water level, 9 miles downstream of NDD No. 5, frequently drops by more than a foot.

Table 4-5 Water Level Change Between Scenario B1 and The NAA (ft.)

Location	Max Water Level Change	Average Water Level Change
Downstream of the NDD No. 5	-4.14	-0.30
3 Miles DS of the NDD No. 5	-3.75	-0.30
9 Miles DS of the NDD No. 5	-2.88	-0.21

The max and average water level change is over the 16 year DSM2 model run

Figures 4-8 through 4-10 show the time series of stage difference between the B1 scenario and the NAA. Figure 4-11 shows the probability of exceedance for the river just downstream of the NDD No. 5. As can be seen in the plot, there is a 10% probability in any year that the water surface elevation will be 1 foot or more below the water level in the no action alternative. This equates to approximately 36 days each year on average. This differs from the stage analysis provided in DWR Exhibit DWR-5 because the data in that exhibit averaged the stage over a day, which filters out the highs and lows.

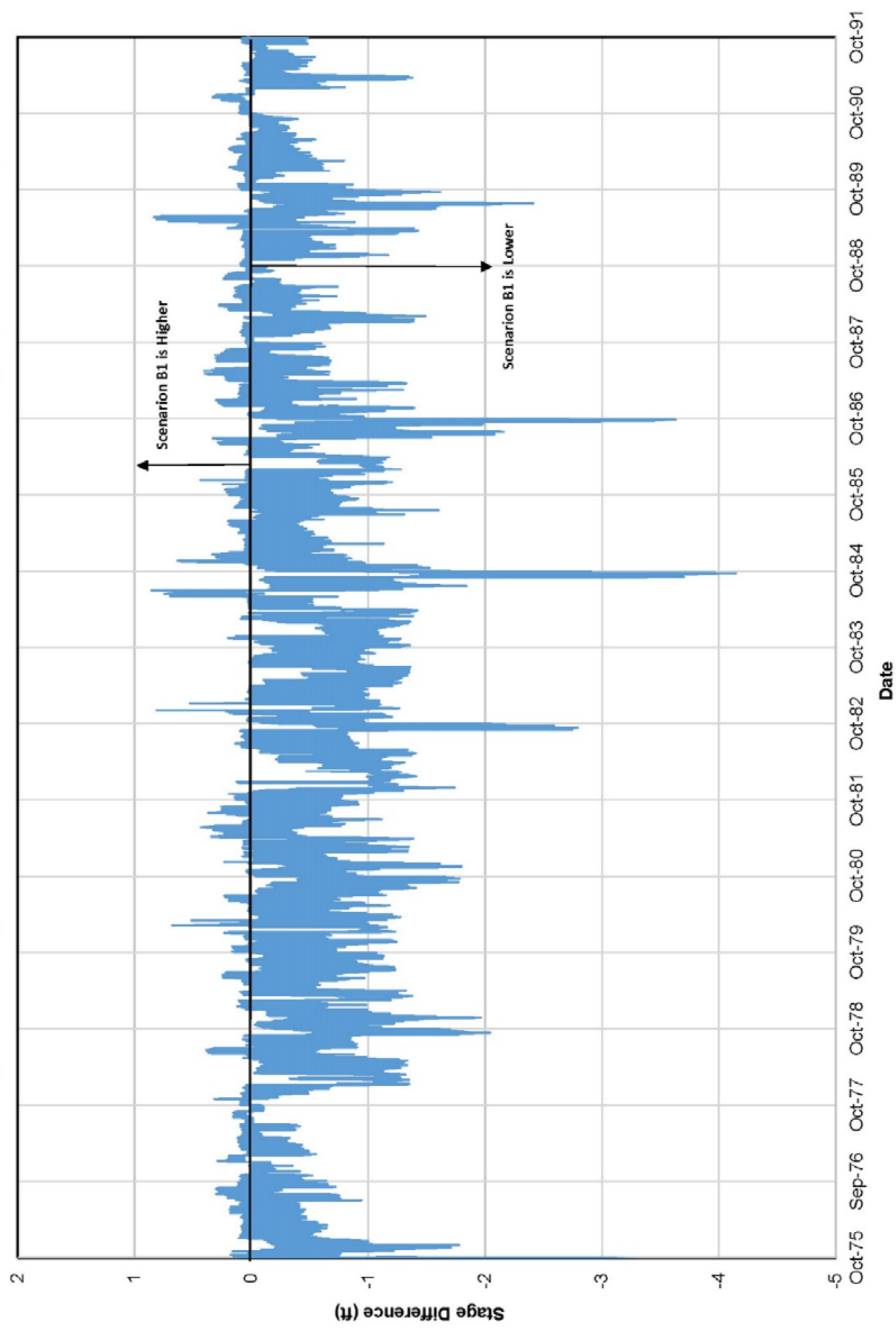


Figure 4-8 Stage Difference Between CWF Scenario B1 and The NAA, Downstream of NDD No. 5

Figure 4-9 Stage Difference Between CWF Scenario B1 and The NAA, 3 Miles Downstream of NDD No. 5

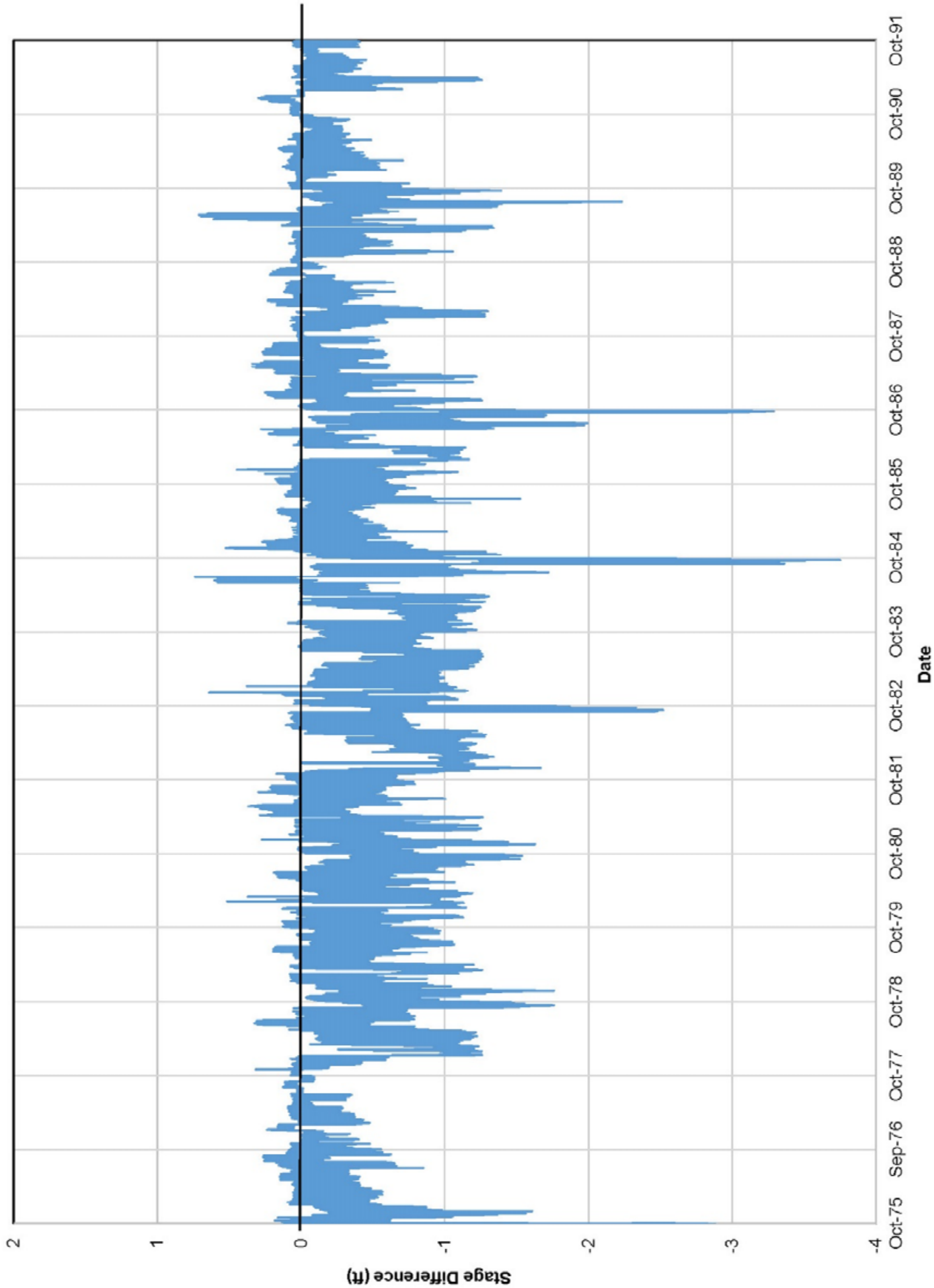


Figure 4-10 Stage Difference Between CWF Scenario B1 and The NAA, 9 Miles Downstream of The NDD No. 5

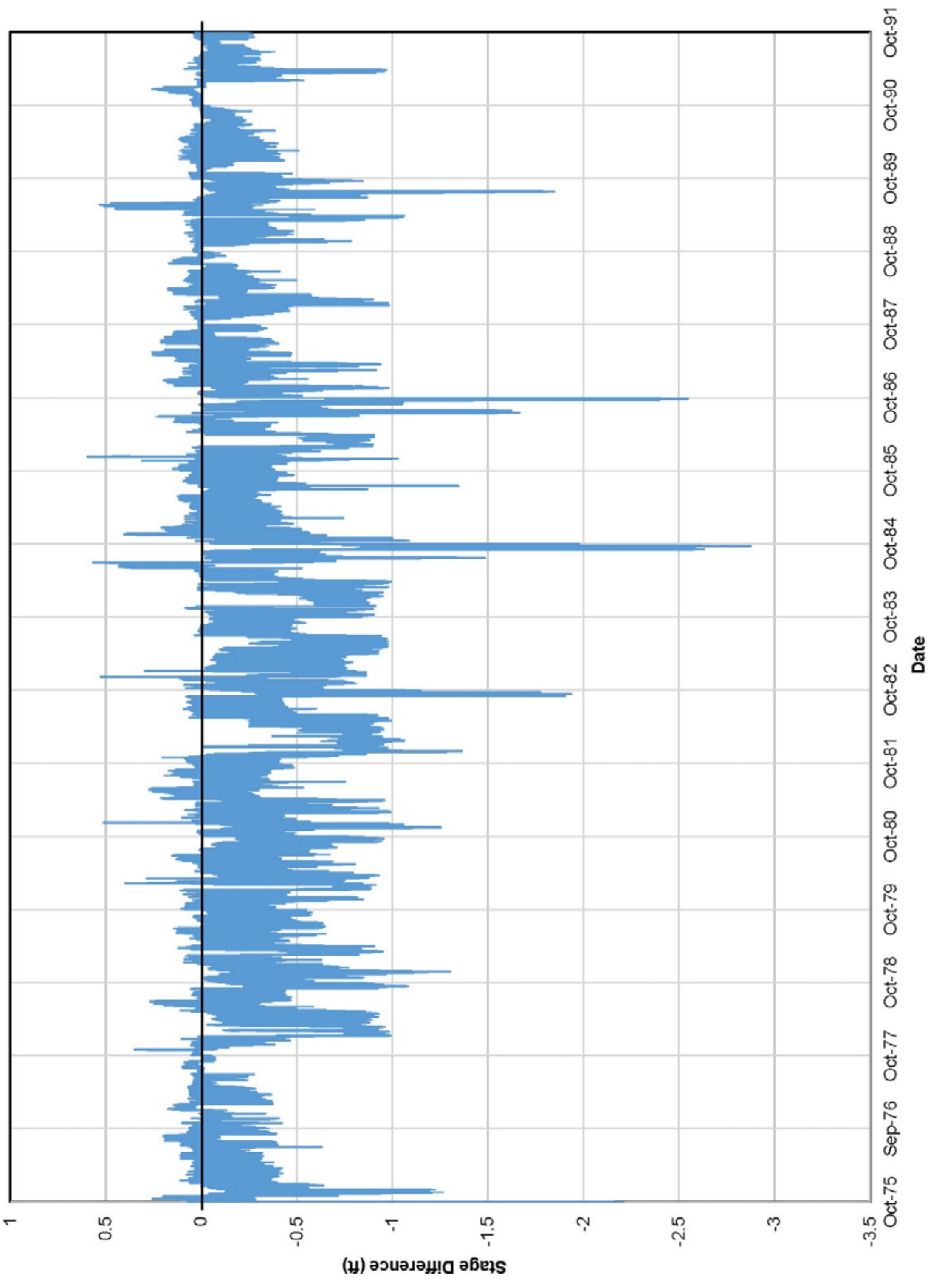
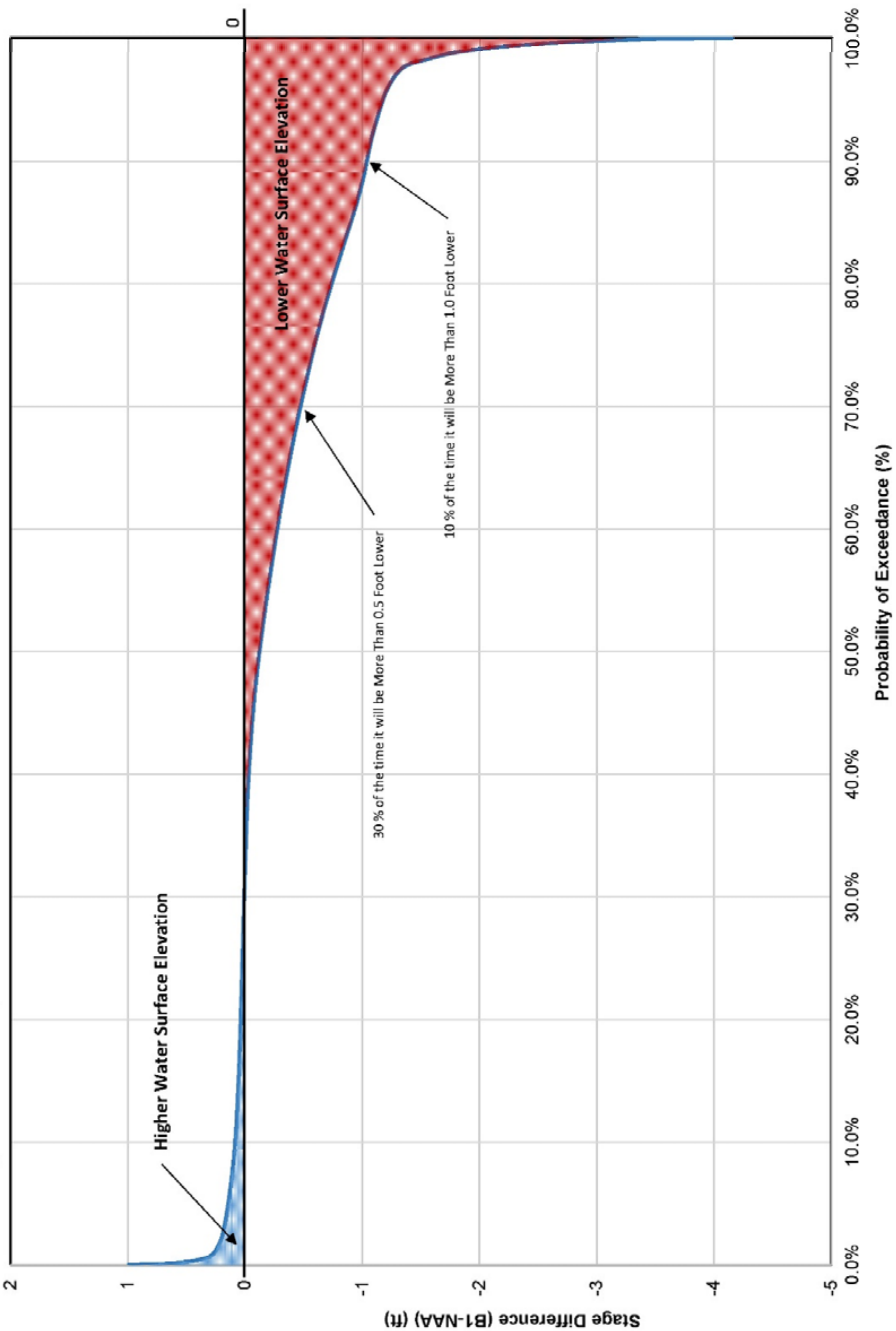


Figure 4-11 Stage Difference Between CWF Scenario B1 and The NAA, Downstream of NDD No. 5



4.4 Project Effects on Algal Growth

Algal blooms have become more and more of a problem in the central and south Delta. Algae tend to grow better in conditions there temperatures are high, there is a ready supply of nutrients, primarily phosphorus, and there is bright direct sunlight. In terms of Delta hydraulics in these areas, algal growth can be delayed or reduced by three factors.

1. The introduction of cooler water.
2. The introduction of water with a lower nutrient content.
3. The steady movement of water out of the Delta through a flushing of the existing water to the west.

The first two items can be affected directly by the change of inflow from the Sacramento River into the Delta. Under the existing condition without the NDD's water from the Sacramento River flows down into the south Delta for Diversion at the Clifton Court Forebay. This water is cooler and has a lower nutrient level than the background water. This cooler water with reduced nutrient load would tend to delay the onset of algal growth and reduce the ultimate algal mass.

The third of the three components has to do with the flushing of water out of the central and south Delta through the normal flow through the system. By moving the water out of the Delta more quickly, you are flushing nutrients and algal mass out of the system.

An analysis was conducted using the Petitioners DSM2 models of the CWF scenarios. The average annual volume of water that is flushed through the Old River and Middle River was calculated for the 16 year period of record. The change in volume between the B1 and B2 scenarios and the NAA was calculated to determine if the scenarios were having an impact on the movement of water through the system. The results of the analysis are shown in Table 4-6. As can be seen in the table, the change in volume moving through Old River ranged from -1.5% to 9.5 %, with the worst case being scenario B2 which had the 9.5 reduction in average annual volume. For the Middle River, the reduction ranged from +4.4% for B1 to -42% for B2. For a system that is already experiencing algal blooms, these reductions in flushing would tend to increase the potential for algal growth.

Table 4-6 Reduction in Flushing Flow For The CWF Scenarios As Compared To The NAA During a Dry Year.[1]		
Scenario	Middle River	Old River
B1	-1.5 %	4.4 %
B2	-9.5 %	-42.0 %
H3	-4.3 %	-0.9 %
H4	-4.5 %	-1.2 %
1. A negative value indicates a reduction in volume moving through the system and a positive value indicates an increase in volume moving through the river.		

5 South of Delta Exports.

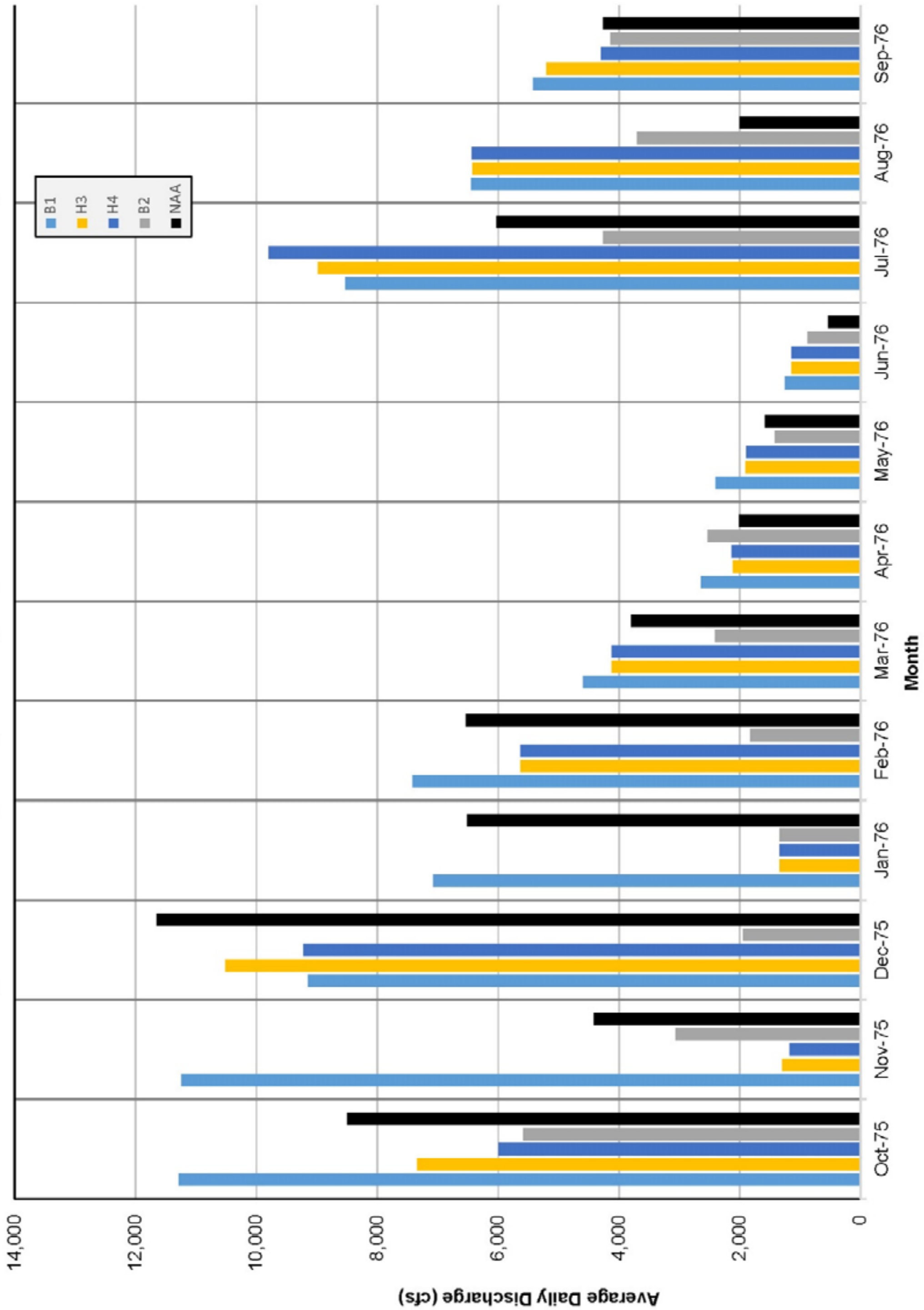
An analysis was conducted to determine the total amount of water that was being diverted through the NDDs and the South Delta Diversions (SDDs) at the Clifton Court Forebay under each of the CWF scenarios. The analysis used the Petitioners DSM2 models to look at the total exported water for each of the CWF scenarios and the NAA. The monthly and annual total exports were calculated for the 16 year period of analysis of the Petitioners DSM2 models. Table 5-1 shows the average annual flow rate and volume as calculated from the DSM2 model data. An analysis was also conducted to see the difference between the CWF scenarios and the NAA. Table 5-2 results of that analysis for the different CWF scenarios. Figure 5-1 shows the monthly distribution of exports for the 1976 Water Year. Figure 5-2 shows the average annual export rate, averaged over the 16 year period of the Petitioners DSM2 model. Scenario B1 has the greatest increase in total exports over the NAA. It ranges from a high of 61% increase over the NAA in 1987 to a low of -6.4 % decrease in 1983. The average for Scenario B1 is a 20.9 % increase over the exports for the NAA. The change in exports over the NAA is highly dependent on the scenario, but overall will increase in B1 and H3 and stay the same or decrease with H4 and B2. The percent change of the CWF scenarios as compared to the NAA each year is plotted in Figure 5-3.

Table 5-1 Average Annual South of Delta Exports (WY 1976 – WY 1991)		
	Average Flow Rate	Average Annual Volume
Scenario	(cfs)	(ac-ft.)
B1	7,168.5	5,194,194
B2	4,436.9	3,214,954
H3	6,322.3	4,581,043
H4	5,895.5	4,271,784
NAA	6,046.7	4,381,394

Table 5-2 Percent Change in Total Annual SOD Exports As Compared To The NAA				
Date	B1	H3	H4	B2
1976	33.9%	-42.8%	-3.1%	-8.1%
1977	11.3%	-32.4%	0.8%	2.0%
1978	25.3%	2.7%	19.7%	14.9%
1979	10.3%	-45.3%	-5.8%	-8.9%
1980	18.0%	-18.0%	8.0%	-8.6%
1981	30.3%	-47.4%	5.6%	-9.2%
1982	29.1%	-6.5%	20.9%	11.1%
1983	-6.4%	-25.4%	-5.5%	-6.9%
1984	12.3%	-23.2%	2.7%	-14.1%
1985	21.0%	-41.7%	-8.7%	-19.0%
1986	11.7%	-26.0%	0.5%	-9.9%
1987	61.0%	-33.2%	7.9%	11.5%
1988	34.7%	-11.9%	19.9%	16.7%
1989	14.3%	-41.9%	10.7%	6.5%
1990	3.1%	-37.4%	-3.8%	0.2%
1991	25.4%	0.1%	12.8%	13.9%

Exhibit SDWA-47

Figure 5-1 Average Daily Discharge By Month Total Total South of Delta Exports For WY 1976



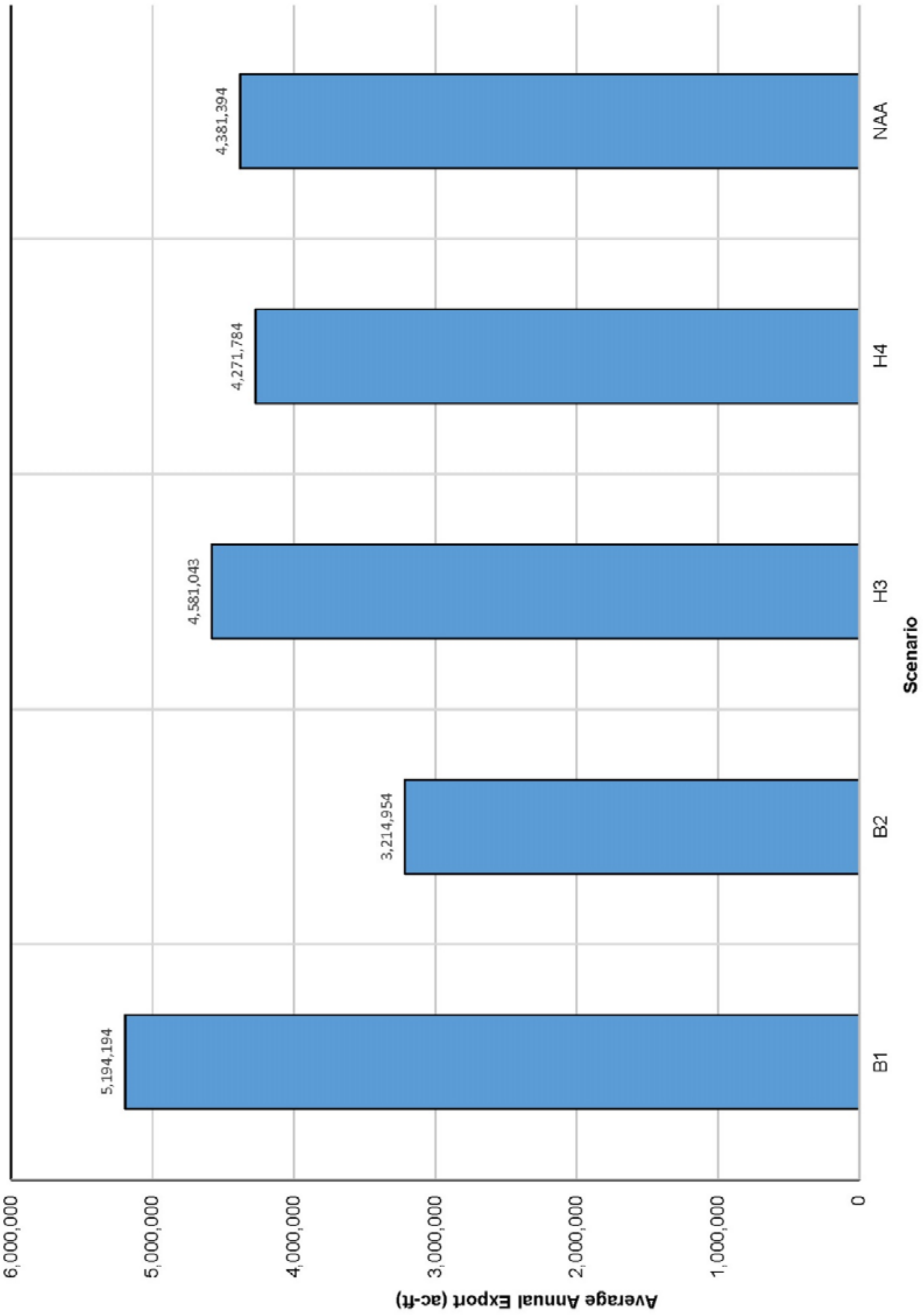
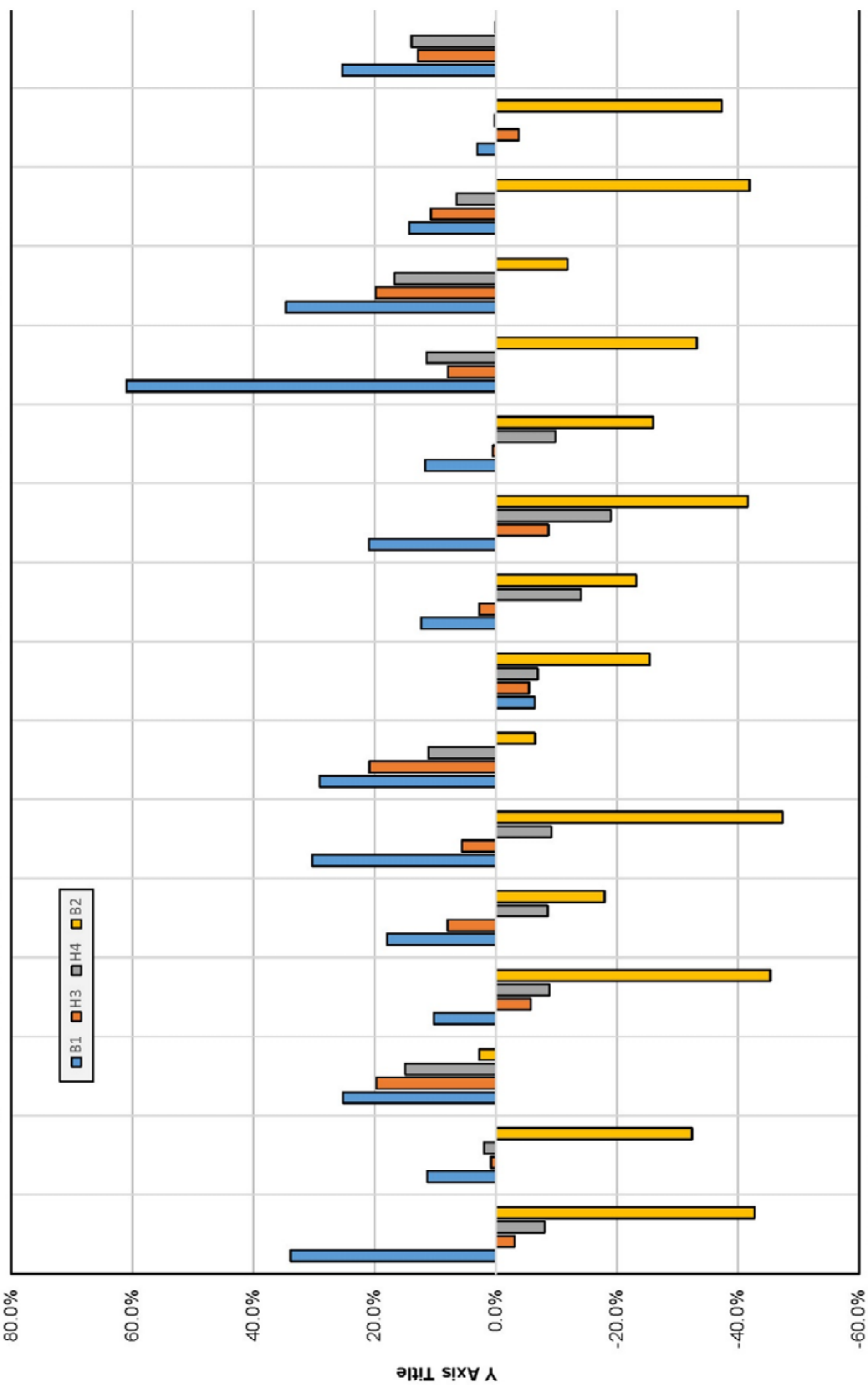


Figure 5-2 Average Annual Total South of Delta Exports (WY 1975-1991)

Figure 5-3 Percent Change In Total South of Delta Exports For The CWF Scenarios As Compared To The NAA



5. Summary

This analysis was conducted to determine what potential impacts may result from the implementation of the CWF scenarios. To avoid any problem with conflicting models, we performed the analysis using the CALSIM II and DSM2 models that were developed by the Petitioners and uploaded the SWRCB FTP Site for the Water Right Change Petition hearing.

Our evaluation showed a frequent increase in salinity at the 17 different sites that we evaluated. Overall the sites had elevated salinity levels about 50% of the time when compared to the NAA. Short duration spikes, sometimes lasting weeks were as high as 650 μS/cm. These high increases were masked by the Petitioners use of annual averages and mean monthly averages taken over the 16 year model run.

We used the DSM2 models to evaluate the change to river stage downstream of the NDD. Comparing the CFW scenario B1 to the NAA alternative, we calculated a maximum water level drop of 4 feet downstream of the NDD, 3.7 feet 3 miles downstream of the NDD, and a maximum change of 2.8 feet up to 9 miles downstream of the diversion point. These are maximums and the average river level drop is less than these maximums, but the river at 9 miles downstream from the diversion still experienced a decline in level for a significant percentage of the year.

The rate of positive flushing of the Old and Middle Rivers was evaluated. The results generally showed a decrease in flushing flow for all scenarios on Old River, and an increase in flushing flow for Scenario B1 on Middle River. All of the remaining scenarios had a reduction in flushing flow for Middle River. A reduction in positive flushing of water within the river will result in an increase in residence time resulting in a potential increase in algal growth.