EBMUD-152

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BEFORE THE

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

HEARING IN THE MATTER OF CALIFORNIA DEPARTMENT OF WATER RESOURCES AND UNITED STATES BUREAU OF RECLAMATION REQUEST FOR A CHANGE IN POINT OF DIVERSION FOR CALIFORNIA WATER FIX	TESTIMONY OF DR. BENJAMIN S. BRAY, Ph.D., P.E.

I, Benjamin S. Bray, do hereby declare:

I. INTRODUCTION AND OVERVIEW OF TESTIMONY

I am a Senior Civil Engineer employed by the East Bay Municipal Utility District ("EBMUD"). I hold a Bachelor of Science in Environmental Resource Engineering from Humboldt State University (2000) and a Masters of Science (2002) and Doctor of Philosophy in Civil Engineering with an emphasis in water resources and minors in operations research and linear statistical models (2006) from the University of California at Los Angeles. I am a registered Civil Engineer in the State of California (C78883), and I have over nine years of experience with EBMUD. A true and correct copy of my statement of qualifications is submitted as EBMUD-127.

In this testimony, I present my analysis and findings regarding potential impacts of the California WaterFix Project ("WaterFix Project") on the operation of the Freeport Regional Water Project ("Freeport Project"). The Freeport Project is owned and operated by the Freeport Regional Water Authority, a joint powers authority of EBMUD and the Sacramento County Water Agency ("SCWA"). Based on my review and analysis of the modeling results provided for this proceeding by the California Department of Water Resources ("DWR") and the United States Bureau of Reclamation ("USBR") (collectively, "Petitioners"), I conclude that, under certain circumstances, the WaterFix Project is likely to increase the frequency and duration of reverse flow events in the Sacramento River that exceed threshold criteria that require the Freeport Project intake facility to temporarily stop diverting water.

The Joint Change Petition ("Change Petition") filed by Petitioners on August 26, 2015 contains no analysis of the WaterFix Project's potential impacts on the Freeport Project. Nor did Petitioners present any such analysis in their written testimony and exhibits filed in support of the Change Petition. Therefore, to determine whether the WaterFix Project may impede the Freeport Project's operation, I performed a technical analysis of the modeling results generated by Petitioners for this hearing from the CalSim-II and Delta Simulation Model II ("DSM2")

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models.[1] Specifically, I analyzed Petitioners' CalSim-II modeling results for output of monthly average flows near the Freeport Project intake for Water Years 1922 through 2003 under each of the five modeling alternatives Petitioners presented. The five alternatives are the No Action Alternative and four project alternatives: H3, H4, Boundary 1, and Boundary 2.[2] I also analyzed Petitioners' DSM2 15-minute velocity output for Water Years 1976 through 1991 to assess the potential project impact on the frequency of reverse flow events that meet or exceed specified shutdown criteria for the Freeport Project intake.[3]

Based on my analysis of the CalSim-II modeling results developed by Petitioners for this Change Petition, I conclude that the implementation of the WaterFix Project will likely cause further Sacramento River flow reductions during seasonally dry conditions. These incremental flow reductions, as compared to the No Action Alternative, result in more frequent reverse flow events that meet or exceed Freeport Project intake shutdown criteria. Increased Freeport Project shutdowns will cause operational disturbances and may result in a loss of water supply to EBMUD and SCWA in critical months during droughts when existing supplies are already deficient to meet existing needs. DSM2 modeling also indicates that the proposed WaterFix Project has the potential to cause Freeport Project shutdowns that would not otherwise have occurred. DSM2 analysis identified 29 months during dry years within Water Years 1976 through 1991 when at least one of the four project alternatives will increase the frequency of

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[1] Petitioners' May 16, 2016 letter to the hearing officers notified the parties of the public availability of "updated modeling relating to the proposed project and modeling on an adaptive operational range." EBMUD subsequently requested that modeling from Petitioners, and I have relied on the modeling Petitioners provided in response to EBMUD's request to prepare this testimony.

[2] For a description of the CalSim-II and DSM2 models as well as additional information on the five alternatives modeled for the Change Petition, refer to testimonies of Jennifer Pierre (Exhibit DWR-51), Parviz Nader-Tehrani (Exhibit DWR-66), and Armin Munévar (Exhibit DWR-71), and the exhibits referenced in each.

[3] Although Petitioners also provided DSM2 modeling results for Water Year 1975, I excluded the Water Year 1975 output data from my analysis to allow a "warm up" period. This approach is consistent with Petitioners' decision not to use Water Year 1975 data, as explained by Petitioners' DSM2 expert, Dr. Parviz Nader-Tehrani, during cross-examination.

reverse flow events that meet or exceed the Freeport Project intake shutdown criteria, as compared to the No Action Alternative.

Taken together, the CalSim-II and DSM2 models demonstrate the potential for Petitioners to shift existing operations upon implementation of the WaterFix Project to alter the timing of their north-to-south exports within a given year. This change may periodically reduce freshwater flows at Freeport, causing more reverse flow events that meet or exceed the Freeport Project intake shutdown criteria.

Section I of this testimony presents this overview of my conclusions. Section II describes how tidal influences affect the Freeport Project intake by causing reverse flows and explains how the Freeport Project must shut down during certain reverse flow events. In Section III, I outline the technical approach I used to analyze the WaterFix Project's impact on reverse flows at Freeport, utilizing results from two models, CalSim-II and DSM2. Section IV presents the findings from my analysis of the modeling performed by Petitioners in connection with the Change Petition. Section V discusses uncertainties and model limitations of this analysis. Finally, Section VI presents several conceptual permit terms that would remedy the injury to EBMUD and SCWA.

II. BACKGROUND

A. Tidal Cycle Influence on Reverse Flows at Freeport.

The Freeport Project intake is located on the Sacramento River near the town of Freeport. The Sacramento River is a major tributary to the Sacramento-San Joaquin Delta ("Delta"). The Delta is subject to natural tidal cycles because it is connected to the San Francisco Bay and, ultimately, the Pacific Ocean. Tidal cycles that drive the rise and fall of large water bodies are a function of the combined gravitational forces exerted by the Moon, the Sun, and the rotation of the Earth. The Delta is a "mixed tide" system, meaning that two uneven tidal cycles typically occur each day with characteristic higher high water, lower high water, higher low water, and lower low water. This tidal cycle is illustrated in Figure 1.

The extent to which tidal cycles affect the Sacramento River at Freeport depends in part on the volume of freshwater flows traveling downstream at Freeport. When Sacramento River freshwater flows are relatively high, tidal influence is more pronounced in downstream reaches, and tidal influence on discharge measurements at Freeport are small or virtually non-existent. However, when Sacramento River freshwater flows are relatively low, tidal influence will extend further up the Sacramento River and up into other Delta tributaries. The tidal influence can even reverse the flow of the river at Freeport for a period of time when Sacramento River freshwater flows are relatively low. Figure 1 shows an example of tidal influence resulting in reverse flows during low tide over a period of three days in April 2015.

B. The Freeport Project Intake Must Shut Down Whenever Reverse Flow Events Exceed Pre-Determined Threshold Criteria.

Reverse flows can require temporary Freeport Project shutdowns. The Freeport Project intake is located near a major wastewater discharge point. The Sacramento Regional County Sanitation District ("Regional San") discharges treated wastewater into the Sacramento River through a wastewater outflow diffuser 1.3 miles downstream from the Freeport Project intake. The discharged wastewater remains downstream of the Freeport Project intake during normal flow conditions, but it can become a concern during reverse flow conditions.[4]

When reverse flows occur on the Sacramento River near Freeport, discharged wastewater from Regional San flows upstream towards the Freeport Project intake. To prevent wastewater effluent from entering the Freeport Project intake, the Freeport Project must stop diverting water immediately when Regional San's wastewater effluent has traveled an average distance of 0.9 miles upstream from its discharge point. This distance of upstream travel is referred to as the "advective transport distance." The Freeport Project intake may not resume operation until the Sacramento River's flow returns to a normal downstream flow and the wastewater effluent zone has retreated downstream to a location not more than 0.7 miles upstream from Regional San's discharge point. These criteria are contained in a coordinated operations agreement between the Freeport Regional Water Authority and Regional San, and they are enforceable conditions of the

[4] The proposed WaterFix Project's diversion point nearest the Freeport Project intake is about four miles downstream of the Regional San wastewater discharge point, between the towns of Courtland and Clarksburg, as depicted on Figure 2.

domestic water supply permit issued to EBMUD by the State Water Resources Control Board ("SWRCB") Division of Drinking Water.[5] Figure 3 contains a graphical representation of the criteria for shut down and resumption of Freeport Project intake operations during reverse flow events.

To meet those criteria, the Freeport Project operators must identify tidal influence on the Sacramento River by monitoring velocities at the Freeport gage around the clock. The Freeport gage is about 1.3 miles downstream of the Freeport Project intake near the Freeport Bridge. The gage has operated since at least 1948 and is a semi-continuous monitoring station of river stage, river discharge, battery voltage, water velocity, water temperature, electrical conductivity, and water turbidity.

C. Reverse Flow Events that Exceed the Freeport Project's Mandatory Shutdown Criteria Have Historically Occurred in Low-Flow Conditions.

To understand the conditions under which SRFEs may occur, I analyzed publicly-available data from the Freeport gage.[6] As used in this testimony, a "significant reverse flow event" ("SRFE") is a reverse flow event that would cause wastewater effluent from Regional San to travel an average of 0.9 miles or more upstream from its discharge point, which is the threshold at which the Freeport Project must stop diverting water.

I applied the Freeport Project shutdown criteria to Freeport gage velocity data between 0100 hours on January 1, 1987 through 2400 hours on January 14, 2016. The gage data indicates that SRFEs corresponded to months with significantly low flows on the Sacramento River, which typically occurred in critically dry years. The monthly distribution is shown on Figure 4. Figure 5 illustrates the relationship between monthly average flows and the frequency of SRFE occurrences in the corresponding month. While the sample size is not large, this historical

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[5] For a detailed discussion of these restrictions, see Exhibit EBMUD-151 (Testimony of Eileen M. White, P.E.) at page 10.

[6] I downloaded the historic Freeport gage data (USGS 11447650) from the California Data Exchange Center ("CDEC"), http://cdec.water.ca.gov/queryCSV.html.

analysis shows an increasing incidence of SRFEs as monthly average flow decreases below 8,000 cubic feet per second ("cfs").

III. ANALYSIS METHODS

My analysis of the potential impacts of the WaterFix Project on the operation of the Freeport Project and associated facilities focused on Petitioners' CalSim-II and DSM2 modeling and the modeling I performed utilizing Petitioners' models. Petitioners' CalSim-II modeling included a longer 82-year period of hydrology (Water Years 1922 through 2003), as compared to the shorter 16-year DSM2 simulation performed for this proceeding (Water Years 1976 through 1991). The longer period simulated with CalSim-II allows assessment of a wider range of hydrology and associated operations. A key advantage of DSM2, as compared with CalSim-II, is its 15-minute velocity output. The modeled velocity at a 15-minute time step is necessary and sufficient to directly identify short-term, tidally-influenced SRFEs. I describe my CalSim-II and DSM2 analysis in the remaining portion of this Section III.

A. Petitioners' CalSim-II Results Were Screened to Identify Months in Which WaterFix Project Operations Increase the Risk of Significant Reverse Flow Events at Freeport.

Petitioners used CalSim-II, a water resources planning model, to evaluate the WaterFix Project and the associated operations of the State Water Project ("SWP") and the Central Valley Project ("CVP"). CalSim-II is a monthly model that quantifies river flows, reservoir storage levels, diversions, return flows, as well as Delta inflows and outflows under various SWP/CVP operating scenarios.

To determine if the WaterFix Project has the potential to change river flow in a manner that may increase the frequency and severity of SRFEs, I compared CalSim-II model results for the Sacramento River immediately downstream of Freeport for the No Action Alternative and each of the four project alternatives. Specifically, I developed and applied a set of Monthly Flow Criteria, which is comprised of three logic statements that I applied as a filter to compare CalSim-II results for the various project alternatives with the No Action Alternative:

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For each project alternative (H3, H4, Boundary 1, and Boundary 2):

1. the monthly average flow below the Freeport Project intake for the project alternative is less than the No Action Alternative, and

2. the monthly average flow for the project alternative is less than the threshold value of 8,000 cfs, and

3. the relative change in monthly average flow between the project alternative and the No Action Alternative is greater than a tolerance of 20 cfs.

The first logic statement above is intended to flag months in which modeled Freeport flows in one of several project alternatives are less than modeled flows in the No Action Alternative.

The second logic statement applies an 8,000 cfs low-flow threshold adopted from my analysis of historical flows recorded by the Freeport gage station. I described that historical data analysis in Section II. That analysis indicates that SRFEs historically occur most frequently when flows drop below 8,000 cfs. On that basis, I applied a criterion of monthly average flow less than or equal to 8,000 cfs as a reasonable threshold indicator variable for assessing the potential for the WaterFix Project to increase the risk of SRFEs.

The third logic statement is simply a tolerance to avoid small changes in monthly average flow that are not expected to impact reverse flow events. Sensitivity on the magnitude of this tolerance is also included in my analysis of results below to indicate how it could affect the risk assessment outcome.

By applying the three Monthly Flow Criteria to screen Petitioners' CalSim-II monthly flow output data, I identified specific months in which Petitioners' WaterFix modeling results indicate that at least one WaterFix Project alternative would reduce flows at Freeport by more than a nominal amount during the type of low-flow conditions historically associated with SRFEs.

To be clear, the months flagged by the Monthly Flow Criteria do not necessarily equate to SRFEs. SRFEs cannot be directly identified from the CalSim-II model output. The strength of a given reverse flow event is a function of several factors, including Sacramento River flow, the specific characteristics of the natural tidal cycle, and operation of key downstream facilities such as the Delta Cross Channel. Detailed modeling of these parameters is not available through CalSim-II. One readily available CalSim-II model output, however, is the monthly average flow immediately downstream of the Freeport Project intake. I used that flow information to identify the relative change in risk of increased reverse flow events due to the WaterFix Project significantly lowering Sacramento River flows relative to the No Action Alternative. This approach is an appropriate comparative analysis that utilizes the CalSim-II monthly output to assess the project effect on the risk of incurring SRFEs that would impact Freeport Project intake operations.

B. Petitioners' DSM2 Results Were Analyzed With and Without Bias Correction to Identify Discrete Significant Reverse Flow Events Resulting from WaterFix Project Operations that Impact the Freeport Project.

1. Overview of DSM2 Methodology

Petitioners used DSM2 to simulate the No Action Alternative and the four WaterFix Project alternatives. DSM2 simulates flow, velocity, stage, and electric conductivity. Petitioners included certain analysis of stage and electric conductivity in their exhibits and written testimony. Petitioners did not provide an analysis of velocity data but did make available the DSM2 15-minute velocity output for Water Years 1976 through 1991. That velocity data can be used to directly assess the effect of the WaterFix Project on Freeport Project intake operations. I compared simulated DSM2 velocity data from Petitioners' historical simulation with actual velocity data from the Freeport gage station data. That comparison revealed that Petitioners' DSM2 results systematically under-predicted peak velocity magnitudes at high and low tide.

To correct that under-prediction bias, I calculated an appropriate velocity offset to apply to Petitioners' DSM2 velocity output to match minimum reverse flow velocities. I calculated the optimal offset by minimizing the sum-of-square error between model simulation and historical Freeport gage data over 15 months of historical low-flow periods in which reverse flow events

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occurred.[7] I applied the optimal offset to the simulated output to align as closely as possible with the actual velocities recorded by the Freeport gage. Applying that offset produced a set of bias-corrected velocity output for assessing reverse-flow impacts derived from the DSM2 output provided by Petitioners. This offset is key because the negative 15-minute velocity output is the basis for calculating the shutdown criteria triggered by the Freeport gage station. If the simulated peak minimum reverse flow velocity is underestimated, then the modeling results will systematically underestimate SRFEs.

I analyzed both the non-bias-corrected output and the bias-corrected output to identify discrete SRFEs in each data set. I describe my methodology in greater detail in the remainder of this portion of my testimony.

2. Method of Analysis of Non Bias-Corrected Velocity Output

I first analyzed Petitioners' DSM2 velocity output data without bias correction. For each reverse flow event (*i.e.* when velocity is negative), I computed the advective transport distance by multiplying the velocity (feet per second) by the time step (seconds). Whenever the accumulated advective transport distance for the reverse flow event met or exceeded 0.9 miles (4,752 feet), I identified that event as a SRFE that would cause a shutdown of the Freeport Project intake. I screened from the results all "non-significant" reverse flow events: those in which the accumulated advective transport distance did not meet the 0.9 mile threshold, because such reverse flow events would not trigger a shutdown of the Freeport Project intake. I then compared SRFEs identified for each of the four project alternatives to the No Action Alternative to determine whether the WaterFix Project would negatively impact EBMUD and SCWA's ability to take diversions through the Freeport Project. I describe the results of that analysis in Section IV of my testimony.

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[7] These were the months of October and November 1990, February 1991, May 1991, May through August 1992, October and November 1992, April through June 1994, December 2008, and November 2009.

3. Bias Correction of DSM2 Velocity Output

Because the DSM2 model consistently underrepresents peak reverse flows at Freeport, I developed and applied a bias correction offset to the raw DSM2 velocity output data. This offset adjusted the simulated velocities to more closely match expected minimum velocities during reverse flow events based on actual Freeport gage station records.

The DSM2 model does not accurately simulate velocity at Freeport at peak high tide or at peak low tide. In both cases, DSM2 tends to understate the peak amplitude. For example, during reverse flow events, DSM2 simulates a reverse flow that is weaker than would realistically occur under the simulated conditions. I identified this bias by plotting Freeport velocity output data generated by Petitioners' DSM2 calibration run against actual velocity data recorded in the same location by the Freeport gage during the simulated period. Two examples from May 1991 and November 1992 are depicted in Figure 6. These graphs show the DSM2 model's continuous under-prediction of river velocities at peak tides. Of direct relevance to reverse flow analysis, the graphs included in Figure 6 specifically show that this under-prediction occurs during reverse flow conditions. In other words, actual measured velocities are consistently more strongly negative than DSM2 has simulated. This means that SRFEs are actually more frequent, and more severe, than estimated from uncorrected DSM2 output. For that reason, I believe that Petitioners' uncorrected DSM2 output data should not be relied upon to determine the impact of the WaterFix Project on the Freeport Project intake.

Instead, a bias correction offset should be applied to match the low-amplitude peak reverse flow velocities with the velocities actually observed at Freeport. I developed a bias offset of -0.230 feet per second by minimizing the sum-of-square error between simulated and recorded peak minimum velocities for the Freeport gage over a 15-month period of historical records in which flows were low enough to contain reverse flow events at the gaging station. I then applied the offset to the 16-year set of velocity output data at the Freeport Project intake. Figure 7 illustrates how applying the offset caused the simulated velocity data to more closely match observed actual reverse flow conditions at Freeport during the reverse flow period when velocity is negative. In my opinion, that bias-corrected data provides a significantly more accurate representation of the Sacramento River's velocity at Freeport under the simulated conditions, and therefore it should be relied upon to analyze the WaterFix Project's impact on shutdown events at the Freeport Project intake.

The uncorrected DSM2 velocity data is not reliable for SRFE analysis. DSM2 is calibrated with the "big picture" of the Delta and all its complexity in mind; it is calibrated to simulate a broad range of criteria under a wide array of conditions. With limitations inherent to any modeling application, model calibration involves tradeoffs in criteria, especially for large and complex systems. By calibrating with the "big picture" in mind, criteria-specific or localized biases are inevitably introduced. When using the model for a specific purpose – in this case, to identify SRFEs – it is both appropriate and necessary to calculate and apply bias correction to maximize the simulation's accuracy in representing reverse flow events for the Freeport gage station. Bias-corrected data derived for reverse-flow analysis purposes should not be used for other purposes (for example, it should not be used to identify peak *positive* flows), but it is the best available dataset to comparatively analyze reverse flows.

After applying the bias correction to velocity data for the full 16-year simulated period to both the No Action Alternatives and the four project alternatives, I identified additional SRFEs not discerned from the uncorrected velocity data. Section IV provides the results of that analysis.

IV. IMPACT ANALYSIS RESULTS AND DISCUSSION

Through my analysis of the WaterFix Project CalSim-II and DSM2 modeling prepared by Petitioners for this hearing, I conclude that the WaterFix Project will likely cause an increase in the frequency and duration of SRFEs that will result in an increase in the frequency and duration of shutdowns of the Freeport Project intake. These impacts are most likely to occur in critically dry years, during the periods in which EBMUD relies on Freeport Project water. This conclusion is based on my analysis of Petitioners' CalSim-II modeling, applying the Monthly Flow Criteria as described above, together with the results of my analysis of Petitioners' DSM2 modeling. My conclusion is consistent with the results of prior independent modeling analysis efforts described below in Section IV.D.

A. CalSim-II Simulations of WaterFix Project Operations Indicate An Increased Risk of Significant Reverse Flow Events During Low-Flow Periods.

I applied the Monthly Flow Criteria over the 82-year period of record as described in Section III.A. As indicated in Table 1, I determined from that analysis that 34 months meet all Monthly Flow Criteria for the H3 project simulation, 22 months meet all Monthly Flow Criteria for the H4 project simulation; 22 months meet all Monthly Flow Criteria for the Boundary 1 simulation; and 20 months meet all Monthly Flow Criteria for the Boundary 2 simulation. These are months in which the WaterFix Project increases the risk of Freeport Project intake shutdowns. As shown in Table 1, such months tend to occur during drought periods. Table 1 provides the total number of months that meet the Monthly Flow Criteria during each of the three major drought periods over the modeled 82-year period: 1929-1934, 1976-1977, and 1987-1992.[8] Depending on which project alternative is analyzed, the WaterFix Project increases the risk of SRFEs relative to the No Action Alternative in 7% to 16% of months during the three identified drought periods.

I also analyzed the sensitivity on the 20 cfs tolerance parameter incorporated into the Monthly Flow Criteria by varying this parameter from a minimum of 0 cfs to a maximum of 150 cfs. Sensitivity results showed that any tolerance parameter between 0 cfs and 150 cfs results in at least a 5% increase in the number of months that meet the Monthly Flow Criteria during the three drought periods identified in Table 1 under all project alternatives relative to the No Action Alternative. This sensitivity analysis demonstrates that the result obtained from application of the Monthly Flow Criteria is relatively insensitive to the choice of the monthly flow tolerance parameter. Among the project alternatives, the H3 simulation was most sensitive to the choice of tolerance parameter, decreasing from 15% to 8.7% as the tolerance parameter increases from 0

[8] For purposes of my analysis, the identified major drought periods commence with the first month of the first dry water year and continue through the month in which the Sacramento River monthly average flow begins to increase with the onset of winter storms at the beginning of the subsequent wet year. The terminal months for these three droughts were October 1934, November 1977, and November 1992.

cfs to 150 cfs. In contrast, the Boundary 1 alternative was least sensitive to the choice of tolerance parameter, decreasing from 8.1% to 6.9% over the same range.

B. DSM2 Simulations Show that WaterFix Project Operations Will Impact the Timing and Frequency of Significant Reverse Flow Events.

I analyzed the DSM2 modeling studies to assess SRFEs directly for the 16-year period simulated by Petitioners (Water Years 1976 through 1991). I did this analysis twice: without bias correction and with bias correction. In both cases, I found the WaterFix Project would alter the pattern of SRFE occurrences, as compared with the No Action Alternative.

1. Analysis of Uncorrected DSM2 Velocity Output Data

Table 2 identifies the total number of modeled SRFEs during the 16-year DSM2 simulation period for the No Action Alternative and each modeled WaterFix Project alternative. Table 2 is based on an analysis of uncorrected raw output data exactly as provided by Petitioners. As shown in that table, the large majority of SRFEs during that period occurred during the droughts in 1976-1977 and 1987-1992. Because dry, low-flow conditions continued into Water Year 1992 – the final year of the latter drought – it is likely that additional SRFEs occurred that year. However, my analysis does not include SRFEs during that water year because Petitioners did not model this sixth year of the drought with DSM2.

Without bias correction applied, the DSM2 analysis reveals a modest overall decrease in SRFEs in each of the four project alternatives in relation to the No Action Alternative. During the 1976-1977 drought, all project alternatives remain within ±4 SRFEs relative to the No Action Alternative. The H4 alternative shows an increase of two SRFEs during that drought. During the simulated portion of the 1987-1992 drought (*i.e.*, excluding Water Year 1992), all project alternatives show a decrease relative to the No Action Alternative.

2. Analysis of Bias-Corrected DSM2 Velocity Output Data

Following my analysis of uncorrected velocity data, I then applied the -0.230 feet per second (ft/sec) offset to correct the model's reverse flow under-prediction bias, and analyzed the corrected data to identify SRFEs under the No Action Alternative and each project alternative. Table 3 presents the results of the analysis of the corrected data. A comparison of Table 3 with

Table 2 reveals the significance of the DSM2 bias. Table 3 shows a much greater incidence of SRFEs under all five modeled alternatives than Table 2. Although the No Action Alternative and the project alternatives all reflect this increase, the corrected modeling results show that SRFEs have the potential for a greater impact on the Freeport Project than the uncorrected modeling results would suggest. It also shows that the WaterFix Project operation will require a greater number of shutdowns of the Freeport Project intake than previously understood, and, therefore, a commensurately greater degree of impact to EBMUD and SCWA.

Table 3 shows a moderate overall decrease in SRFEs under the project alternatives during drought periods relative to the No Action Alternative. Note that Table 3, unlike Table 2, shows increased SRFEs during the 1976-1977 drought in three of four project alternatives simulated.

Comparing overall SRFE totals alone does not adequately convey the totality of the WaterFix Project's impact on the Freeport Project. Because impacts may depend upon not only how many SRFEs occur, but also upon *when* they occur, I analyzed patterns in the distribution of SRFEs throughout the year, comparing the No Action Alternative with the project alternatives. Aggregating SRFEs by month, as I present in Figure 8, reveals how WaterFix Project operations could lead to a disproportionate share of SRFE impacts in some months. The DSM2 analysis shows a tendency for SRFEs to increase relative to the No Action Alternative in a few different ways. There are small changes among the project scenarios in January through April. There tends to be a small decrease in May and June with Boundary 2 showing the smallest change relative to the No Action Alternative. There is not much change in July, and SRFEs would decrease significantly under all project alternatives in August due to increases in Sacramento River flows. September through December show a higher potential for increased SRFEs over various project alternatives. In September, the H3, H4, and Boundary 1 project alternatives all increase SRFEs significantly relative to the No Action Alternative, while September SRFEs would decrease under Boundary 2. A comparison of project alternatives with the No Action Alternative also shows increases for H3 in October and Boundary 2 in December. Figure 8 shows that operation of the WaterFix Project will likely impact the timing of SRFEs – most prominently in fall and winter months before storm events occur.

C. A Comparative Analysis of the CalSim-II and DSM2 Modeling Shows How Shifted Export Patterns Will Change Flows and Thereby Increase Significant Reverse Flow Events, Especially During Drought Periods.

After I analyzed Petitioners' CalSim-II and DSM2 modeling separately, I analyzed the results from both models together to understand how changes in flows simulated in CalSim-II translate to changes in SRFE impacts on the Freeport Project intake simulated in DSM2.

1. Comparison of Flow Data and SRFEs

My comparative analysis revealed 29 separate months during the 1976-1991 period simulated by Petitioners in which one or more of the four project alternatives would increase SRFEs relative to the No Action Alternative, listed in Table 4. These 29 months are the months during the DSM2 modeling period when the WaterFix Project could cause additional shutdowns of the Freeport Project intake. The impacts tend to become more frequent as drought periods progress. For example, 1977 has a higher proportion of SRFEs than 1976. Similarly, 1990 and 1991 had more SRFEs than 1987 and 1988. These impacts are clearly concentrated in droughts when the Sacramento River freshwater flows are lowest. Table 4 also shows that at least one project alternative increases SRFEs in every month between December 1990 and August 1991, except May 1991.

Table 4 directly compares the DSM2 and CalSim-II analysis for each modeled alternative. The -0.230 ft/sec offset was applied to the DSM2 output data for the No Action Alternative and all project alternatives. Table 4 includes all months in which DSM2 analysis, after application of the offset, indicates that at least one project alternative would increase the number of SRFEs relative to the No Action Alternative. The left portion of the table indicates the number of SRFEs under the DSM2 modeling for each modeled alternative. The portion of the table on the right provides corresponding monthly average flow information from CalSim-II, including flows in the No Action Alternative, each project alternative, and the difference relative to the No Action Alternative.

The data provided in Table 4 supports the incorporation into the Monthly Flow Criteria of 8,000 cfs monthly average flow below Freeport as a reasonable threshold indicator of SRFE potential for time periods when DSM2 data is not available. During the months included in Table 4 – all months when SRFEs would occur – flows at Freeport ranged from a high of 31,355 cfs in November 1981 under Boundary 1 (a flow that corresponds to one modeled SRFE) to a low of 5,826 cfs in October 1977 under the H3 alternative (a flow that corresponds to 43 SRFEs). Table 4 also shows the lack of a perfect correlation between flows and the number of SRFEs. For example, under the Boundary 1 simulation, 18 SRFEs occurred in October 1990, corresponding to a flow of 6,870 cfs, but 28 SRFEs occurred in September 1990 despite slightly lower flows of 6,842 cfs. While flows are an important factor in determining SRFEs' number and severity, tidal and operational characteristics also play a key role.

2. Connection between WaterFix Project SRFE Impacts and Shifts in the Timing of Exports

Petitioners assert that the WaterFix Project's purpose is to enhance operational flexibility for the SWP and CVP through the use of three new points of diversion in the north Delta. The CalSim-II and DSM2 results, when considered together, show how WaterFix Project operators could use that new flexibility to shift the timing of north-to-south Delta export patterns. Such shifts will, at times, result in lower Sacramento River flows, with an accompanying increase in SRFEs.

I present two months as examples to illustrate this impact: September 1977 and June 1991. I chose these months because they represent two examples where the Delta is in "excess" and "balanced" conditions, respectively.[9] First, I compared the DSM2 modeling under the No Action Alternative to the H3 project alternative for September 1977. As shown in Table 4 and Figure 9, DSM2 results for that month indicate that SRFEs increase from 17 under the No Action Alternative to 37 under H3. CalSim-II indicates that, under H3, the timing of total water exports "shifts" to earlier in 1977 than under the No Action Alternative. Figure 10 shows this shift in

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[9] Excess conditions are periods when releases from upstream reservoirs plus unregulated flow exceed Sacramento Valley inbasin uses, plus exports. Balanced conditions are periods when releases from upstream reservoirs plus unregulated flow approximately equal the water supply needed to meet Sacramento Valley inbasin uses, plus exports.

total export timing for those two alternatives. Figure 10 shows that exports increase under the H3 alternative in April through August and November and December but are reduced in September and October. The reduction in exports in September and October under the H3 alternative corresponds to decreased Sacramento River flows at Freeport from 6,916 cfs to 6,058 cfs during the same period, as shown on Figure 11.

I also compared the No Action Alternative and Boundary 1 alternative for June 1991. Again, I found that shifting export patterns resulted in periods with lower flows, which were associated with an increase in SRFEs. Figure 12 shows the total exports for these two alternatives and indicates a shift in the timing and quantity of exports under the project alternative relative to the No Action Alternative. In this case, the Boundary 1 project alternative shows significantly increased exports in March through May, relative to the No Action Alternative, along with smaller increases in September through December, coupled with corresponding decreases in June, July, and August. This corresponds to a decrease in Sacramento River flows in June, July, and August as shown in Figure 13. The reduced flows associated with shifting export patterns in June 1991 result in increased SRFEs. Figure 14 shows the DSM2 velocity output for June 1991 for the No Action Alternative and the Boundary 1 project alternative. Figure 14 shows that operating WaterFix to the Boundary 1 alternative caused SRFEs to increase from 4 to 12 during June 1991, compared to the No Action Alternative. Stated another way, 8 new SRFEs occurred in June 1991 that would not occur in the absence of the WaterFix Project.

These examples from 1977 and 1991 show how the operational flexibility that Petitioners seek through the WaterFix Project will allow them to shift the timing of exports, which will cause lower Sacramento River flows at certain times, resulting in more SRFEs at those times than would have occurred without the WaterFix Project. More broadly, the examples show the importance of looking beyond raw SRFE totals aggregated over many years to understand how WaterFix Project will impact the Freeport Project.

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D. My Results are Consistent with Previous Modeling Efforts by DWR and Independent Modelers that Concluded the North Delta Diversion Will Impact Significant Reverse Flow Events at Freeport.

The modeling that Petitioners released in May 2016 for this water rights hearing is not the first time that a project very similar to WaterFix has been modeled. In fact, DWR simulated the operation of three new intakes of the same capacity, in the same location, with the same or similar set of assumed bypass flow criteria and other operational limitations used in the WaterFix Project modeling in 2013 when it performed CalSim-II and DSM2 modeling of the Bay-Delta Conservation Plan ("BDCP"). The key difference between the BDCP and the WaterFix Project is that the former project included a suite of environmental measures including tidal marsh restoration that are not included in the WaterFix Project.

In 2014, EBMUD analyzed DWR's DSM2 modeling of the BDCP to determine whether the BDCP would increase SRFEs.[10] That analysis showed that 25,000 acres of tidal marsh restoration would reduce reverse flows at Freeport, even in conjunction with the new north Delta intakes. However, that analysis also showed that building new intake tunnels without tidal marsh restoration – as Petitioners now propose to do through the WaterFix Project – would increase SRFEs at Freeport. The results of EBMUD's analysis of DWR's modeling are presented in Table 5.[11] Those results show the BDCP, including tidal marsh restoration, would significantly reduce the number of SRFEs at Freeport – from 70 to 14, or from 178 to 21, depending on which planning horizon and associated climate change and sea level rise assumptions were simulated.

A related modeling effort was made by MBK Engineers and Daniel B. Steiner. MBK and Steiner removed climate change and sea-level rise assumptions from the BDCP CalSim-II modeling and modeled the new Delta tunnels with and without tidal marsh restoration. EBMUD then conducted DSM2 modeling of MBK and Steiner's CalSim-II model results, and analyzed those DSM2 results to identify how SRFEs are affected by the respective effects of tidal marsh

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[10] See Exhibit EBMUD-176 (July 28, 2014 comment letter on the BDCP Draft EIS/EIR.

[11] This table is taken from Exhibit EBMUD-176, page 176.

restoration and the new Delta tunnels. Table 6 shows the results of EBMUD's DSM2 modeling and analysis.[12] I draw two conclusions from Table 6. First, the north Delta diversion and the tidal marsh proposed in the BDCP, when constructed together, would result in a net reduction in SRFEs at Freeport. Second, in the absence of tidal marsh restoration, operation of new north Delta intakes would incrementally increase SRFEs from 55 to 64 over a modeled 16-year period. In other words, the BDCP without restoration would cause SRFEs to increase, which is generally consistent with the results of my analysis of the WaterFix Project.

V. MODEL LIMITATIONS AND UNCERTANTIES

My analysis demonstrates that the WaterFix Project will likely cause an increase in the frequency and duration of SRFEs, especially in critical drought months. Although my analysis relies on Petitioners' CalSim-II and DSM2 results, I conclude the WaterFix Project may cause greater SRFE impacts than Petitioners' modeling predicts – even after correcting for DSM2's systematic under-prediction bias of reverse flows. This section of my testimony explains the basis for my opinion.

A. Petitioners' Chosen Modeling Methods Do Not Sufficiently Capture Relatively Rare Events Such as Significant Reverse Flow Events.

CalSim-II is a planning model that operates in broad terms of spatial discretization or coarse terms in temporal discretization. Such planning models tend to perform poorly in capturing relatively atypical or rare events. SRFEs are by definition rare events, and thus, not identified well from CalSim-II modeling. However, CalSim-II is also foundational, meaning that much of the other modeling for the WaterFix Project is tiered from or built upon the CalSim-II results, as is the case for the DSM2 model. DSM2 provides model output of velocity on a 15-minute time step, which allows SRFEs to be directly analyzed where daily averaged results or monthly results would be insufficient. To perform this analysis, however, CalSim-II and temporal downscaling techniques are required to map monthly conditions to the temporal scale required for the DSM2 model simulation. Accordingly, the analysis of 15-minute velocity

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[12] This table is taken from Exhibit EBMUD-176, page 177.

output from DSM2, even in a comparative sense, is necessarily limited because the CalSim-II monthly results are a significant factor in assigning boundary conditions to the DSM2 model.

B. DSM2 Insufficiently Modeled Reverse Flows Because of Inherent Model Limitations, and the Model Was Inadequately Modified to Properly Represent the Proposed Project Changes.

DSM2 is not the best available tool to analyze reverse flow impacts. DSM2 is a one-dimensional hydrodynamic model of flow, velocity, stage, and electric conductivity. The single linear dimension does not accurately represent the complexity of hydrodynamic alterations due to the three proposed north Delta intakes on the Sacramento River. Two- or three-dimensional modeling of this region of the Sacramento River would provide a clearer picture of the WaterFix Project's impacts, including effects on hydrodynamics and specifically reverse flows and velocity.

Petitioners also failed to modify DSM2 cross-sections to represent physical changes to the river channel cross-sections that are proposed as part of the WaterFix Project. For example, Petitioners did not modify DSM2 to account for the modifications to levees and to represent the intake structures. Petitioners also failed to modify roughness coefficients to represent the reduction in roughness expected to result from replacing levees with massive fish screen intakes. Those changes – the physical modifications and the reduced roughness – would tend to increase velocity of reverse flow events. This increase is not captured in Petitioners' modeling.

C. The CalSim-II and DSM2 Models Are Unable to Account for the Broad Range of Operational Flexibility Afforded by the WaterFix Project.

Petitioners modeled four project alternatives, which they claim represent the full range of reasonably foreseeable operational possibilities. Those four alternatives – H3, H4, Boundary 1, and Boundary 2 – each contain operational assumptions. Essentially, those assumptions define the outer limits of the modeled domain and constrain the results of Petitioners' modeling. That constraint would not be objectionable if the modeled scenarios truly represented the full range of plausible operational scenarios. However, each of Petitioners' modeled alternatives assumes an unwarranted and artificial degree of constraint on the project operators' ability to release water from storage during summer and fall. In fact, Petitioners' modeling does not reflect the full extent of operational flexibility afforded by the WaterFix Project, which would enable operators to move stored water through the Delta while meeting all flow criteria and water quality objectives to an extent that is currently not possible. For a detailed discussion of this issue, see the testimony of Walter Bourez of MBK Engineers, which the Sacramento Valley Water Users have submitted into the record for this water rights hearing. Mr. Bourez's conclusions have important implications for SRFEs at Freeport. The WaterFix Project can be operated to "shift" the timing of exports to a greater degree than is revealed by Petitioners' modeling. If those shifts are more pronounced, they would be accompanied by periods of lower flows than previously understood. In turn, those lower flows would generally be expected to increase the frequency and duration of SRFEs – as discussed in Section IV.C of my testimony above.

Petitioners' modeling also does not account for temporary urgency change petitions and orders. The recent drought showed that Petitioners seek and obtain temporary urgency changes. Temporary urgency changes are not represented in Petitioners' modeling, and if allowed in the future, they could cause lower flows on the Sacramento River than simulated by Petitioners' CalSim-II modeling. Finally, without an operations plan and only the proposed north Delta bypass flow criteria, limited information is available to assess intake impacts during real-time operations when reverse flows will need to be addressed.

D. Petitioners' Brief 16-Year Simulation Period Excludes Several Significant Low-Flow Events and Therefore Limits the DSM2 Modeling's Usefulness in Understanding How the WaterFix Project Will Impact Reverse Flows.

Petitioners' DSM2 model results are unnecessarily limited by Petitioners' choice of a 16-year simulation period. That 16-year period excludes several significant simulated low-flow months in which SRFEs would be expected to occur, as inferred from the 82-year CalSim-II simulation. My analysis demonstrates that most low-flow instances occur in the fall, before the onset of winter storm events, and typically in months near the end of drought periods. For example, close inspection of the CalSim-II monthly average flow results at Freeport reveals that the lowest monthly average flows – close to or below 6,000 cfs – occurred in September and

October 1934 and May 1977, and the lowest monthly average flow at Freeport simulated over all four project alternatives was the Boundary 2 simulation, which identified a flow of only 5,121 cfs in November 1992. However, among the four months highlighted above from 1934, 1977 and 1992, only one of those months – May 1977 – is included in the DSM2 modeled period, and this month shows an increase in flows under the project alternatives.

VI. PROPOSED PERMIT TERMS OR CONDITIONS

In this section, I propose a few possible ways to alleviate the WaterFix Project's potential to impact the Freeport Project's intake operations. This section is not intended to be an exhaustive set of options; rather, it is presented merely to demonstrate that there are alternatives not addressed by Petitioners that could reduce the WaterFix Project's impact on EBMUD and SCWA.

A. Require Adequate Tidal Marsh Restoration to Mitigate the WaterFix Project's Impact on Significant Reverse Flow Events at Freeport.

Petitioners' water rights permits could be conditioned on Petitioners' construction of tidal marsh in a quantity and at a location that is demonstrated by modeling to be sufficient to completely prevent the anticipated increase in SRFEs at the Freeport Project intake. The Bay-Delta Conservation Plan ("BDCP") modeling studies show that construction of a sufficient acreage of tidal marsh will mitigate the potential reverse flow effects on the Sacramento River near Freeport. Petitioners' BDCP Early Long Term ("ELT") simulations analyzed the impact of 25,000 acres of tidal marsh restoration. Restoration on that scale was effective in *significantly* reducing reverse flows on the Sacramento River. Table 6 quantifies the dramatic impact of large-scale tidal marsh restoration. A smaller-scale restoration project may be sufficient to prevent the WaterFix Project from causing SRFE impacts. However, additional studies would be needed to optimize the acreage and location of a sufficient tidal marsh restoration project.

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B. Require New or Enhanced Bypass Flow Criteria to Ensure that Freshwater Flows are Sufficient to Mitigate the WaterFix Project's Impact on Significant Reverse Flow Events at Freeport.

A minimum flow criterion at Freeport could be placed into Petitioners' water rights permits that is sufficient to prevent an increase in SRFEs at Freeport. However, a singular flow prescription would likely be too rigid a requirement, as there should be some consideration for environmental conditions such as the natural tidal cycle. Alternatively, Petitioners' proposed north Delta bypass flow criteria could be modified such to ensure that minimum flows downstream of the new north Delta intakes remain sufficient to dampen tidal effects further upstream on the Sacramento River. Additional studies would be needed to develop a Freeport bypass flow requirement that is sufficiently protective to eliminate any increase in SRFEs while maintaining the greatest possible degree of flexibility for the WaterFix Project. Specifically, analysis would be needed to assess which flows are required under different tidal conditions and for different Delta Cross Channel operations.

C. Require Petitioners to Provide Additional Water to Compensate for Impacts from Significant Reverse Flows Events at Freeport.

Petitioners' permits could be conditioned to require Petitioners to provide additional water to EBMUD or SCWA, as applicable, when SRFEs occur. This "make-up" water would then be made available later in the contract year. This would incentivize project operators to adaptively manage the SWP and CVP projects to minimize SRFEs, and when unavoidable, provide for and coordinate the delivery of make-up water to compensate for lost supplies when the Freeport Project intake is shut down. Project operators are skilled and experienced in managing the projects under real-time conditions. Project operators would likely be able to adaptively manage the system to minimize SRFEs and consider the tradeoff between shifting diversion patterns against the risk of necessarily providing make-up water supplies if offsets in diversions are necessary at other times of the year.

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VII. CONCLUSION

The WaterFix Project, as currently proposed, would increase the frequency and duration, and impact the timing, of SRFEs at Freeport Project intake, which will require additional shutdowns. However, protective terms and conditions could be included in Petitioners' water rights to mitigate those SRFE-related impacts.

Executed this 31st day of August, 2016 in Oakland, California.

DR. BENJAMIN S. BRAY, Ph.D., P.E.

FIGURES and TABLES

FIGURES 1—14

Figure 1. Tidal Characteristics with Freeport Gage Discharge, April 19-21, 2015.
Source: http://cdec.water.ca.gov/ Station "FPT", on an hourly basis.

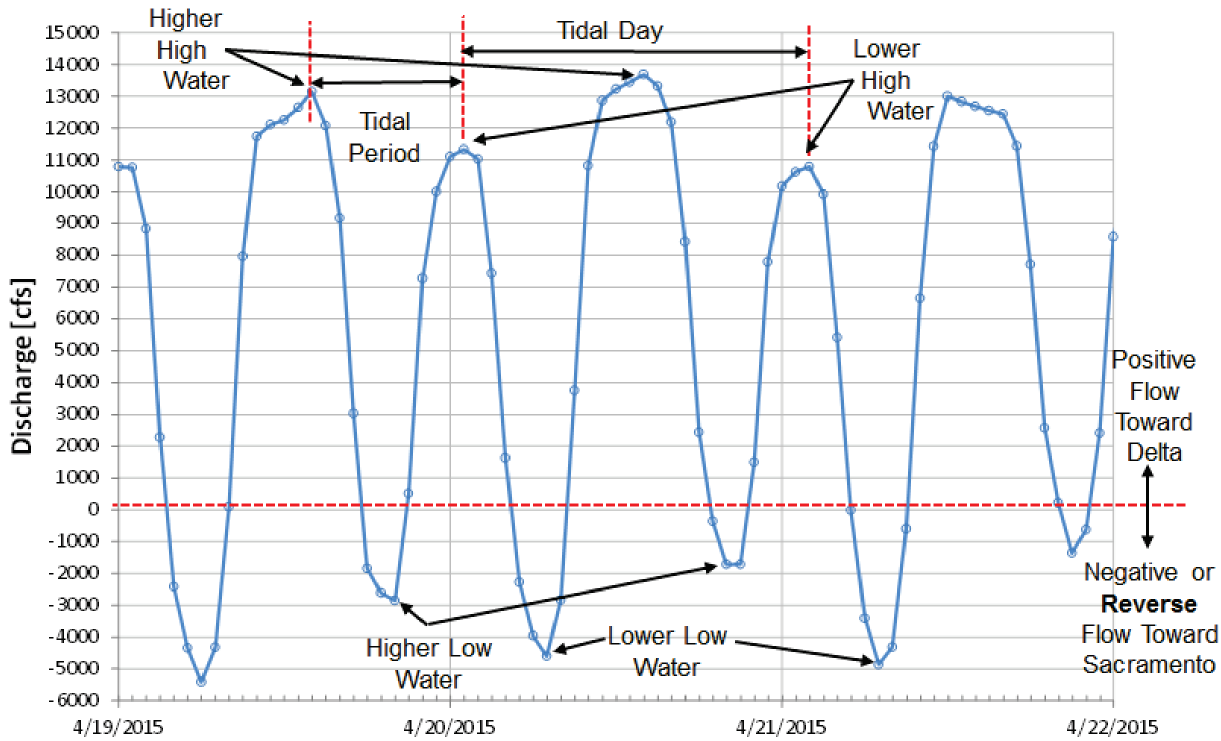


Figure 2. Map Showing Approximate Locations of Freeport Regional Water Project Intake Facility in Relation to Sacramento Regional County Sanitation District and Proposed Intakes for CAWF.

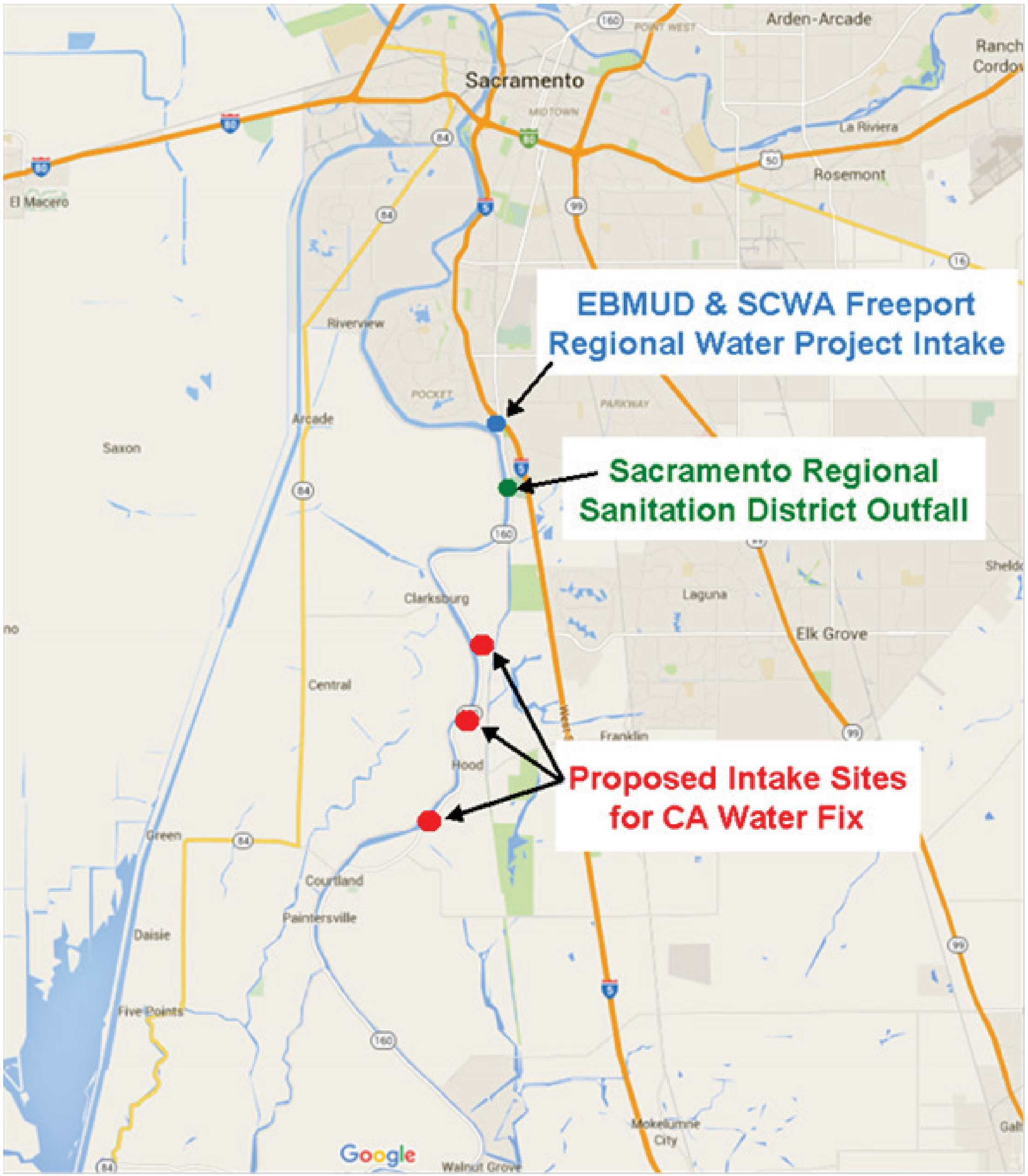


Figure 3. Graphical Representation of Reverse Flow Event Criteria for FRWP Intake Shutdown and Startup in Relation to Regional San and FRWA Facilities. Note locations are approximate for illustrative purposes.

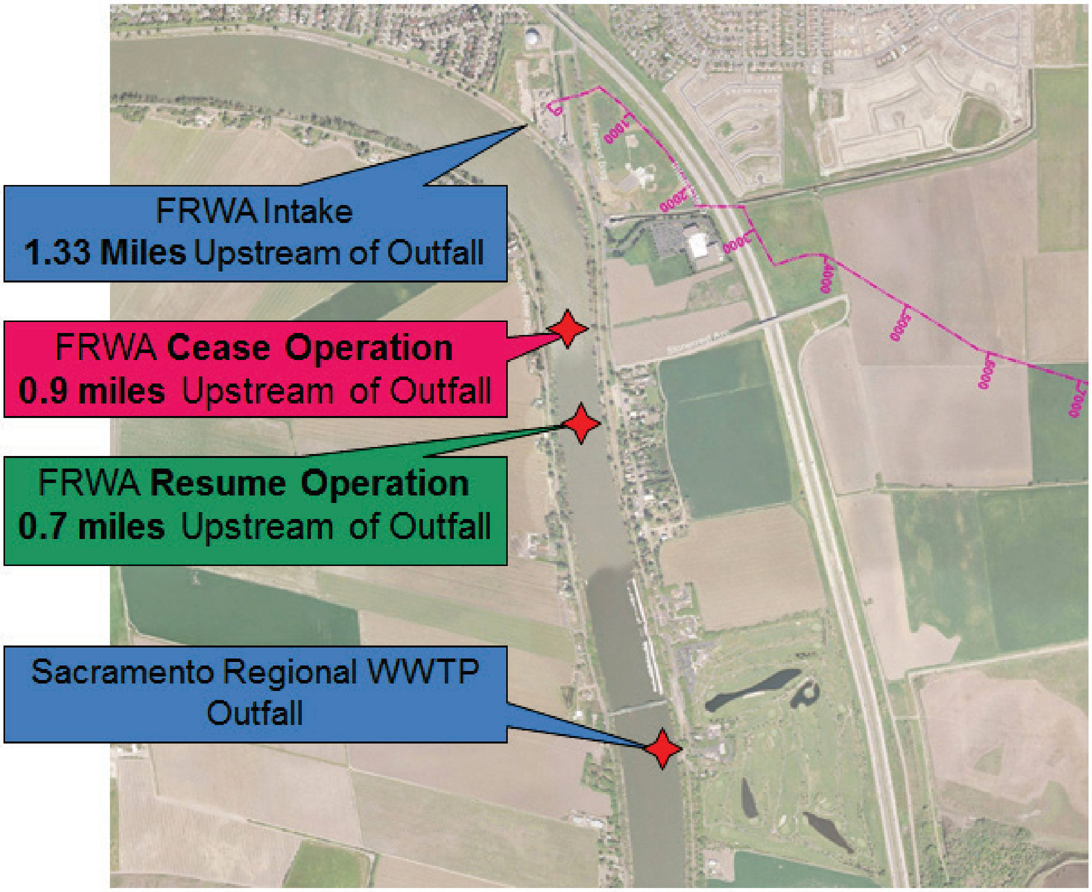


Figure 4. Historical Significant Reverse Flow Events Meeting or Exceeding Advective Transport Distance Criteria Aggregated by Month, January 1, 1987 – January 14, 2016.

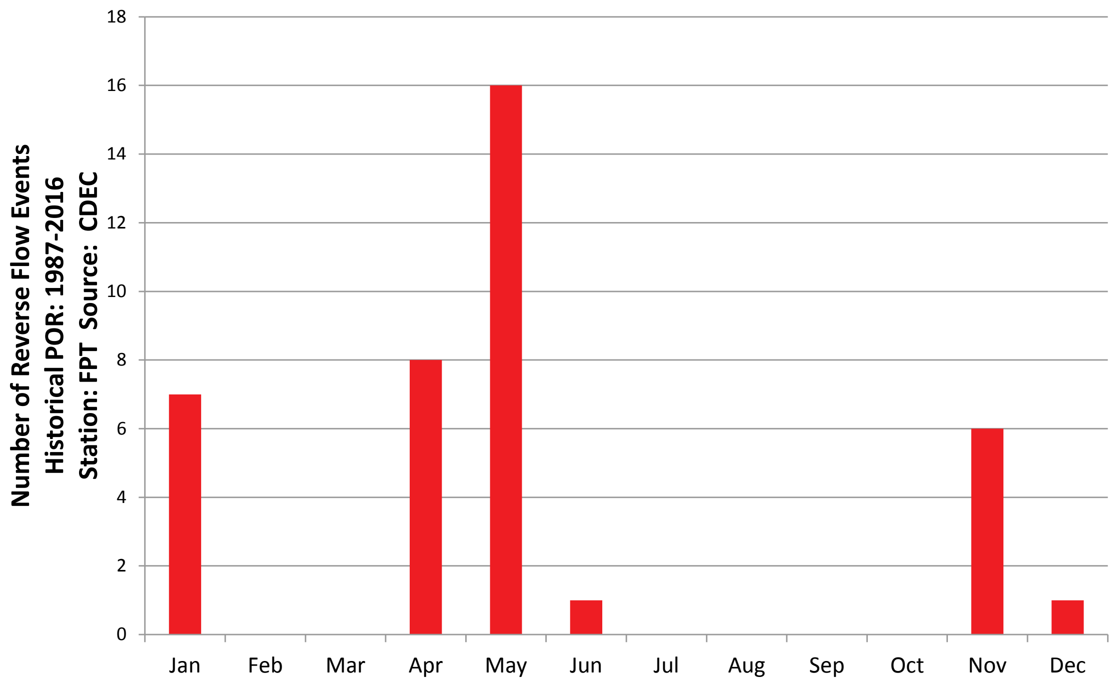


Figure 5. Calculated Monthly Average Flow and Corresponding Number of Reverse Flow Events that Meet Advective Transport Distance Criteria, January 1, 1987 – January 14, 2016.

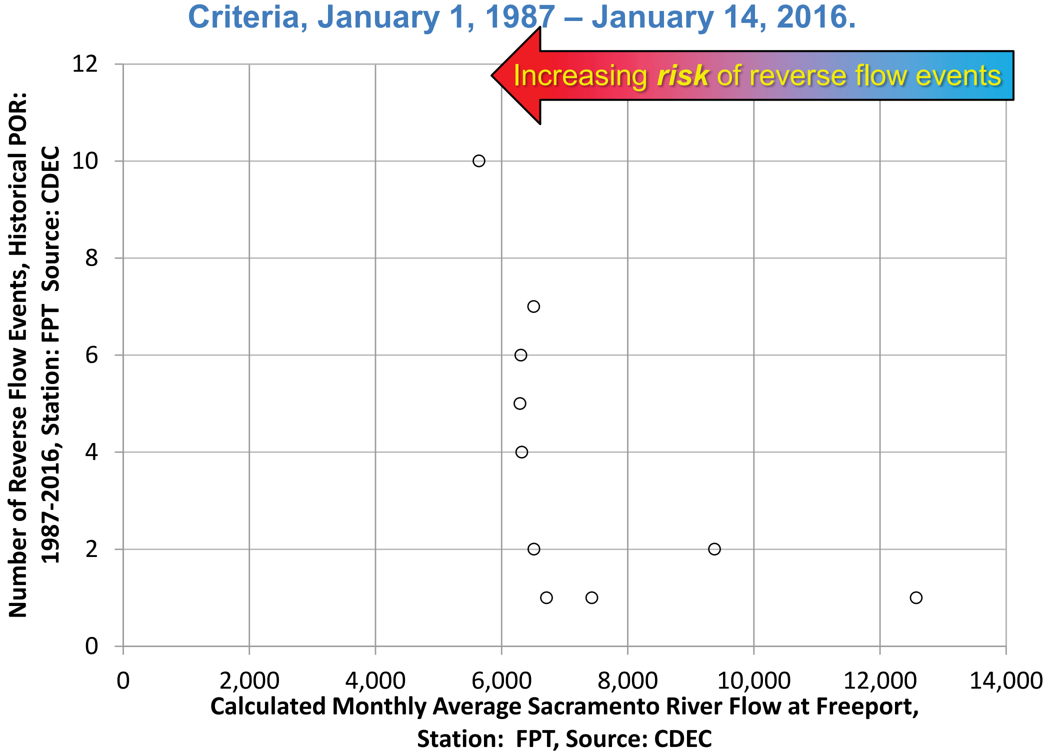
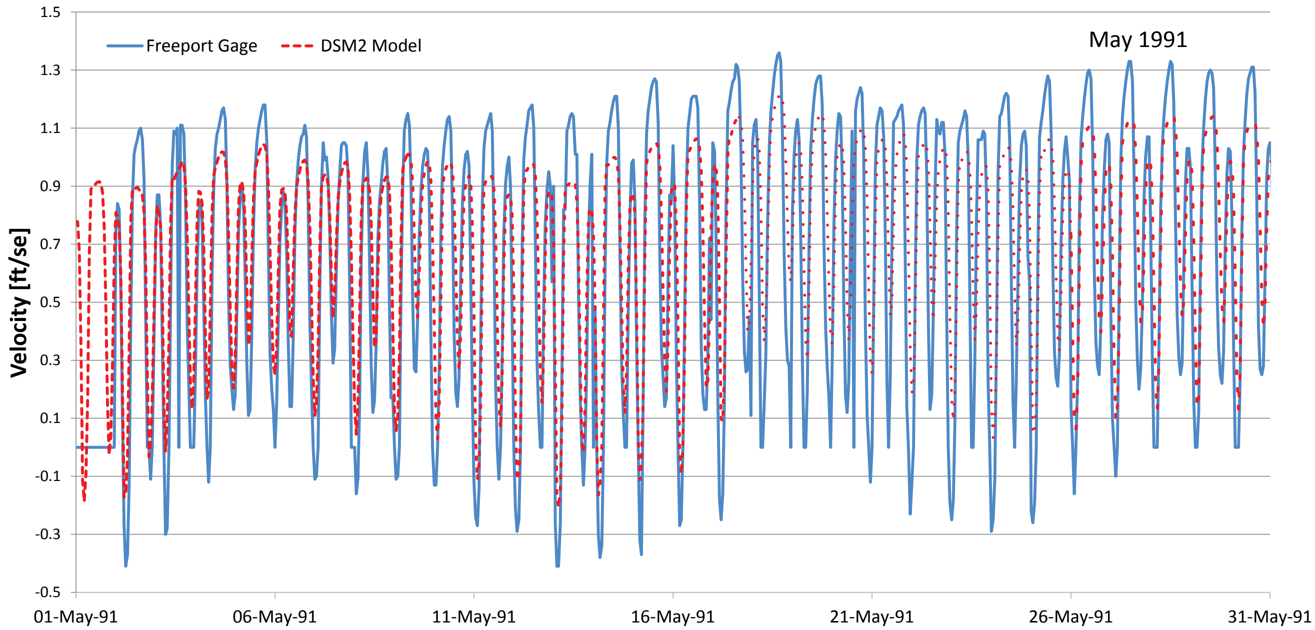
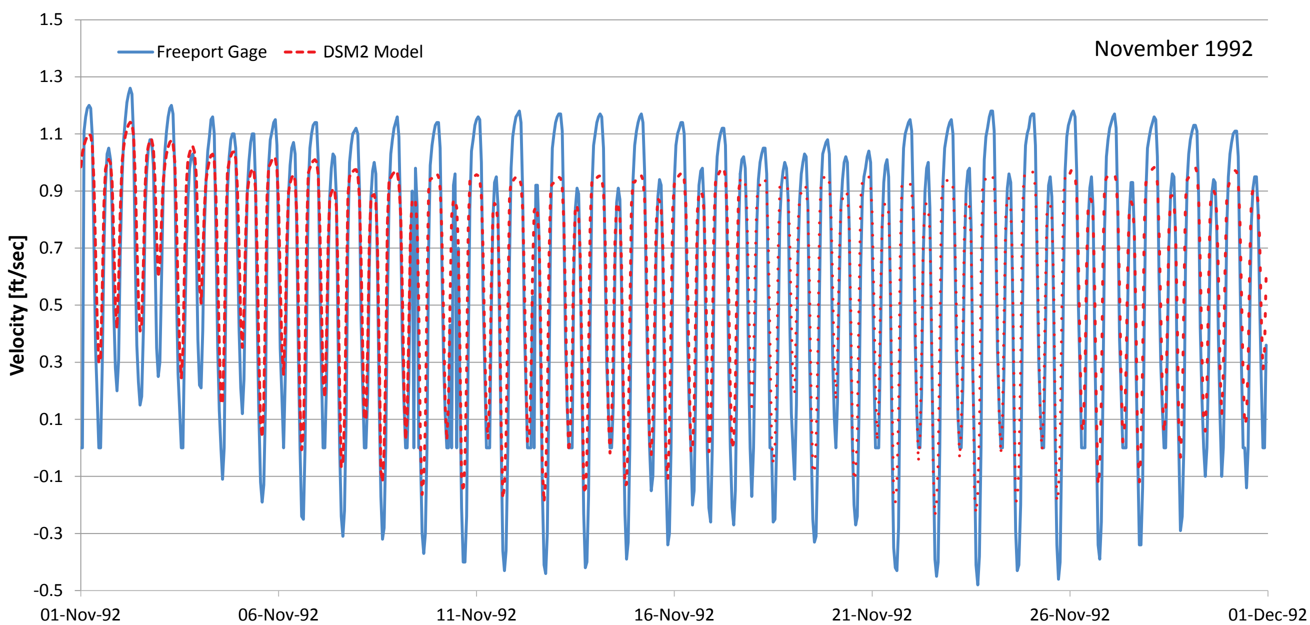


Figure 6. Freeport Gage Velocity with DSM2 Historical Simulated Velocity at Freeport Project Intake, (a) May 1991 and (b) November 1992.



(a)



(b)

Figure 7. Freeport Gage Velocity with DSM2 Historical Simulated Velocity at Freeport Project Intake and DSM2 Velocity with -0.230 ft/sec Bias Correction Offset, Feb. 9 – 27, 1991.

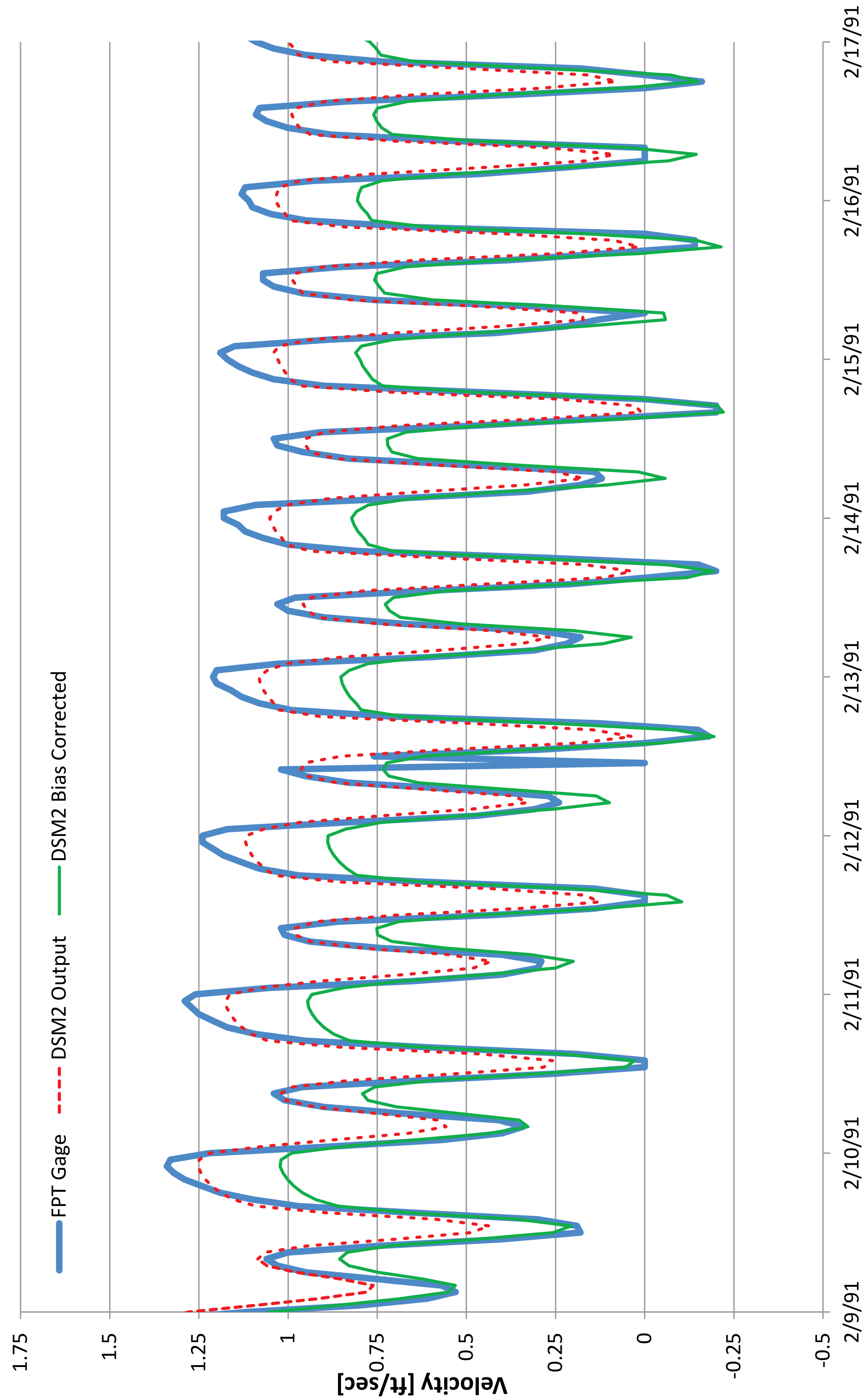


Figure 8. Significant Reverse Flow Events from Petitioner's Bias Corrected DSM2 Simulation of WYs 1976-1991 Aggregated by Month.

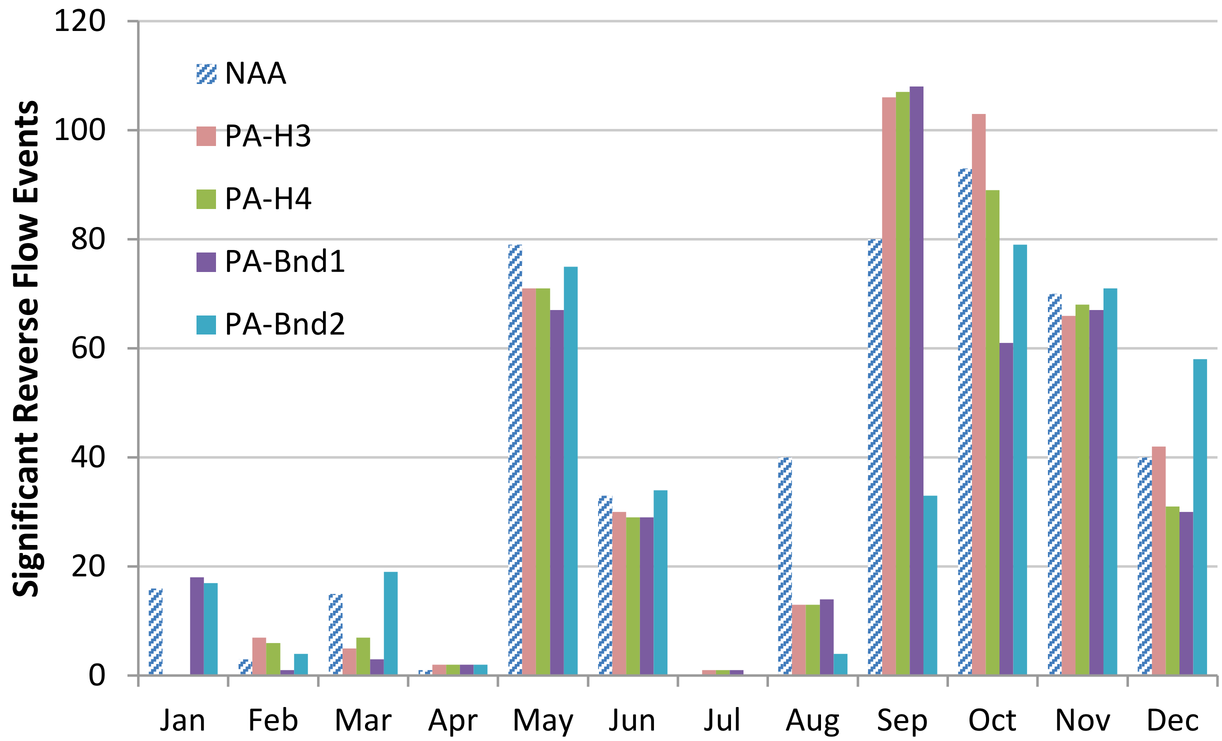
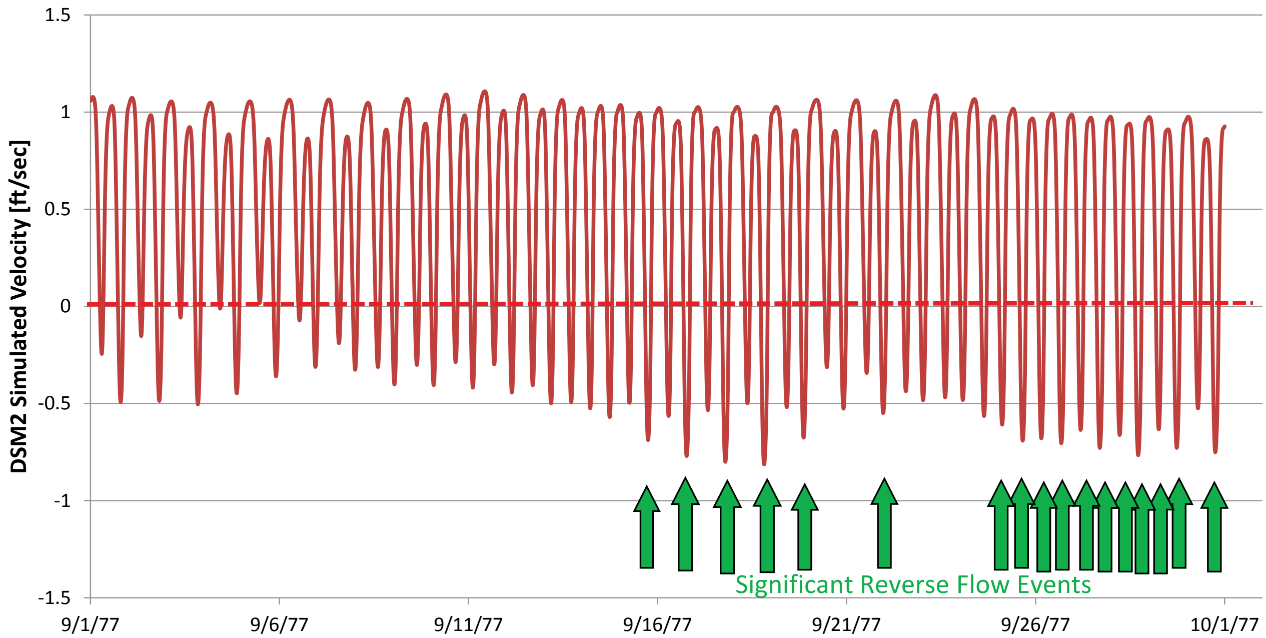
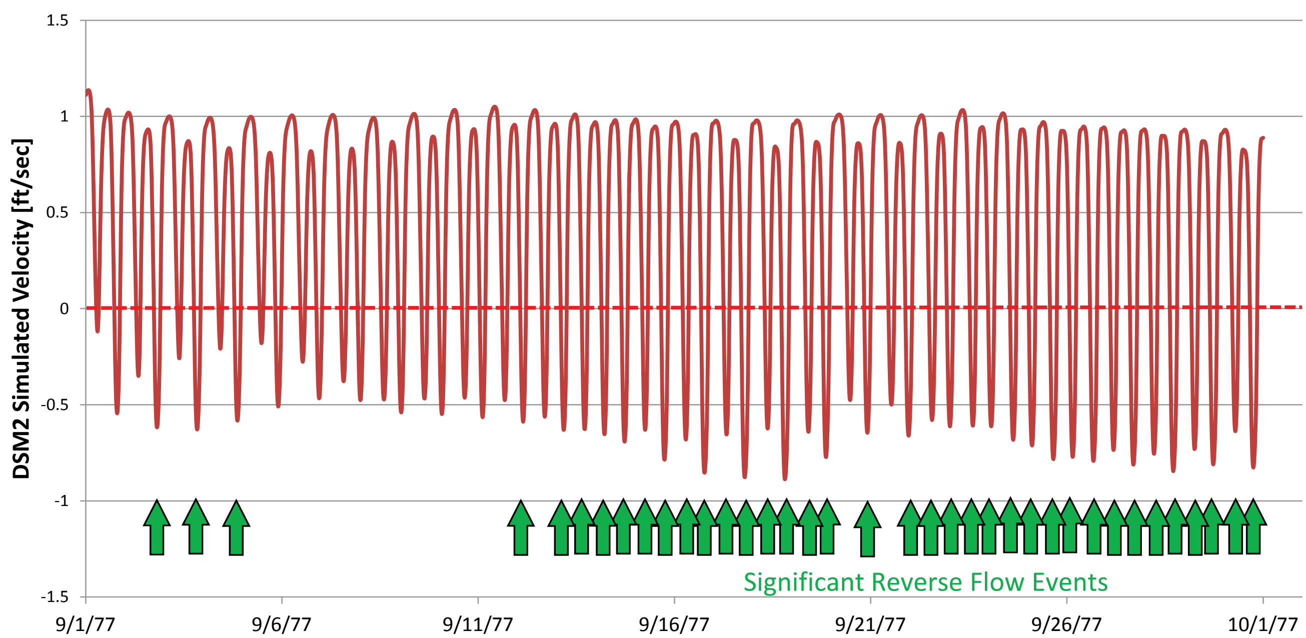


Figure 9. DSM2 Simulated Velocity at Freeport Intake, September 1977 for (a) NAA Scenario (*N*=17) and (b) H3 Project Alternative (*N=37*). Green arrows indicate significant reverse flow events that meet or exceed Freeport Project intake shutdown criteria.



(a)



(b)

Figure 10. Total Exports for NAA and H3 Project Alternative, October 1976 – December 1977. Total Exports for Project Alternative are North + South diversions and from south Delta only for NAA.

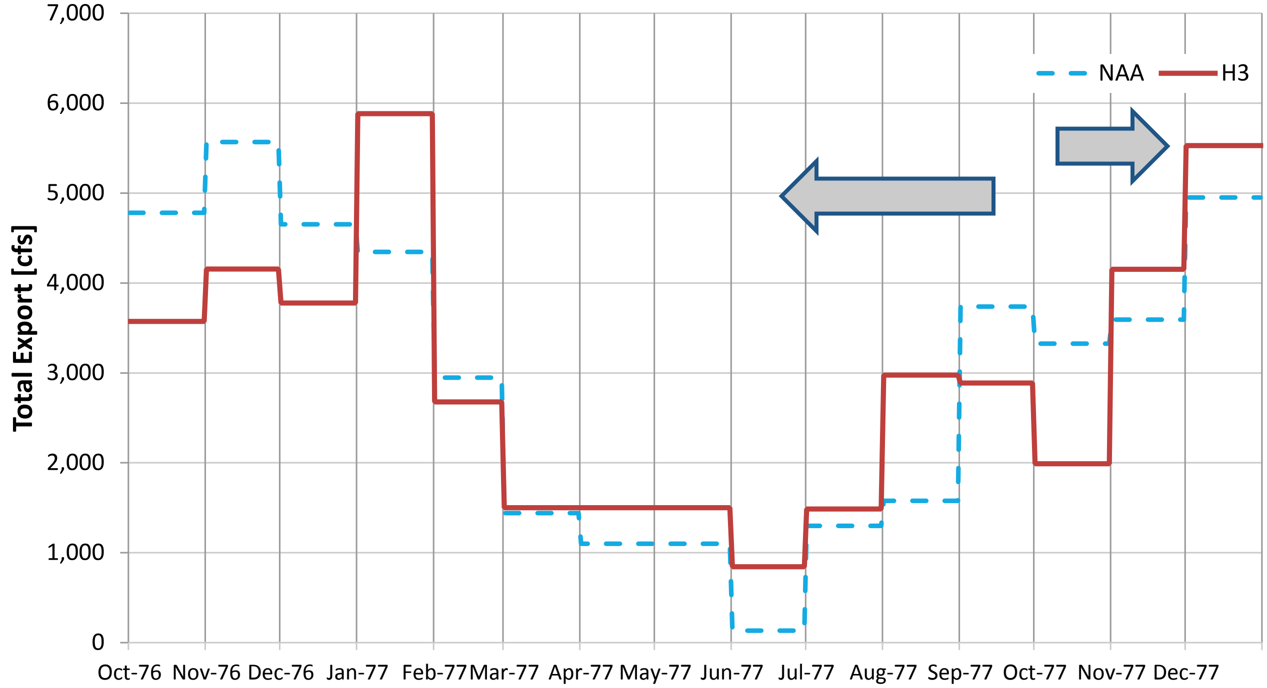


Figure 11. Sacramento River Flow Downstream of FRWP Intake for NAA and H3 Project Alternative, October 1977 – December 1977.

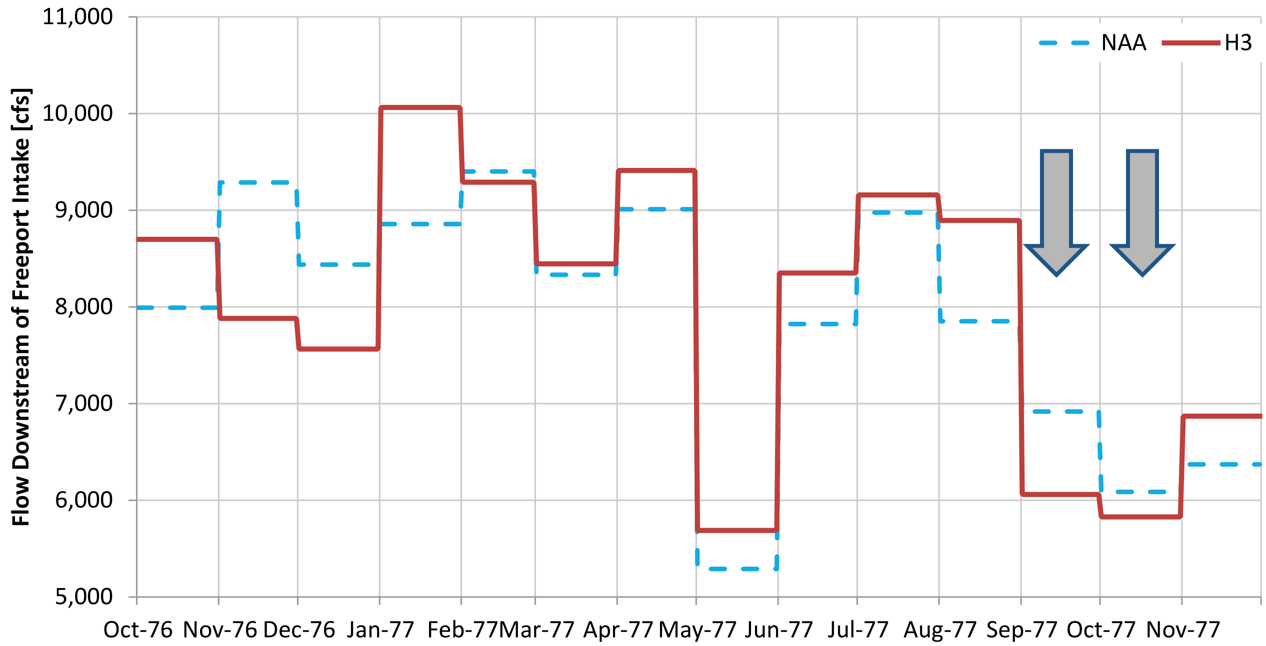


Figure 12. Total Exports for NAA and Boundary 1 Project Alternative, October 1990 – December 1991. Total exports for Boundary 1 are north + south diversions and from south Delta only for NAA.

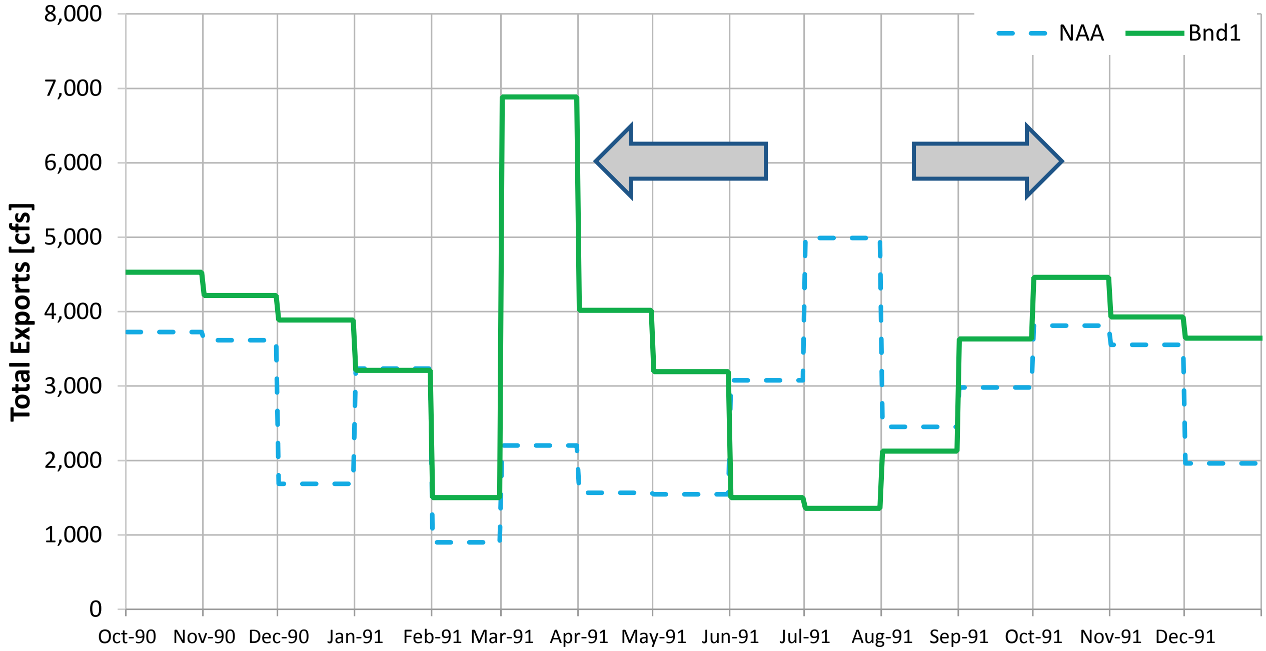


Figure 13. Sacramento River Flow Downstream of FRWP Intake for NAA and Boundary 1 Scenarios, October 1990 – September 1991.

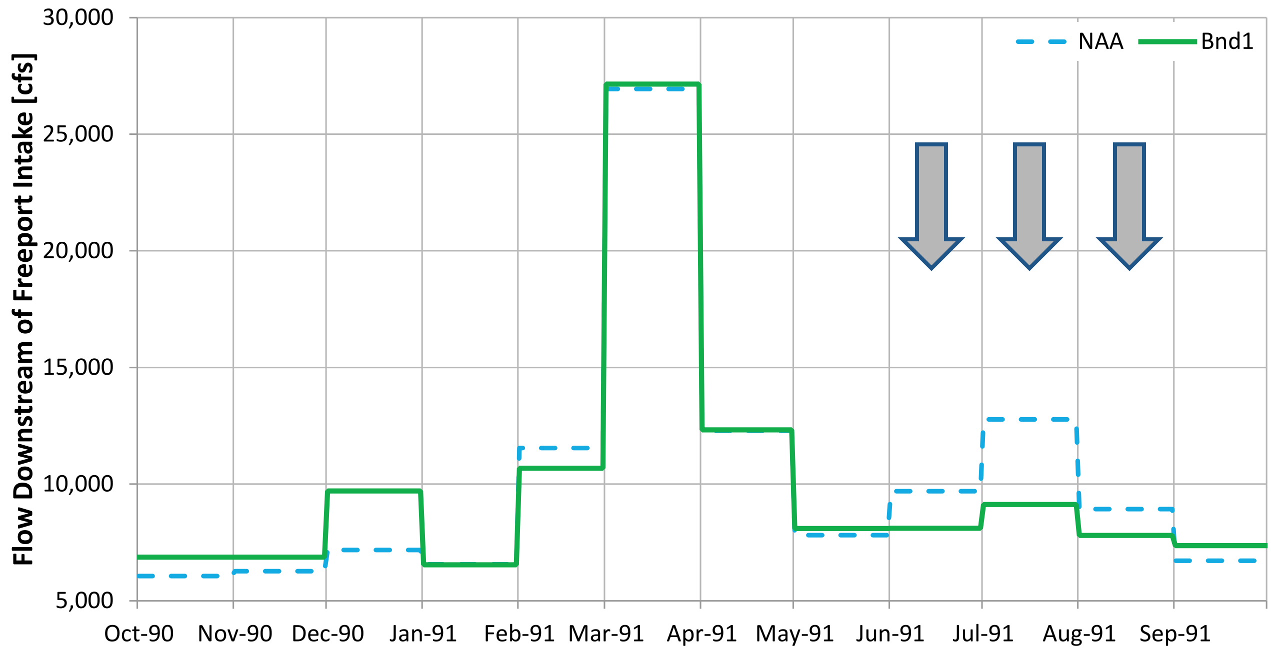
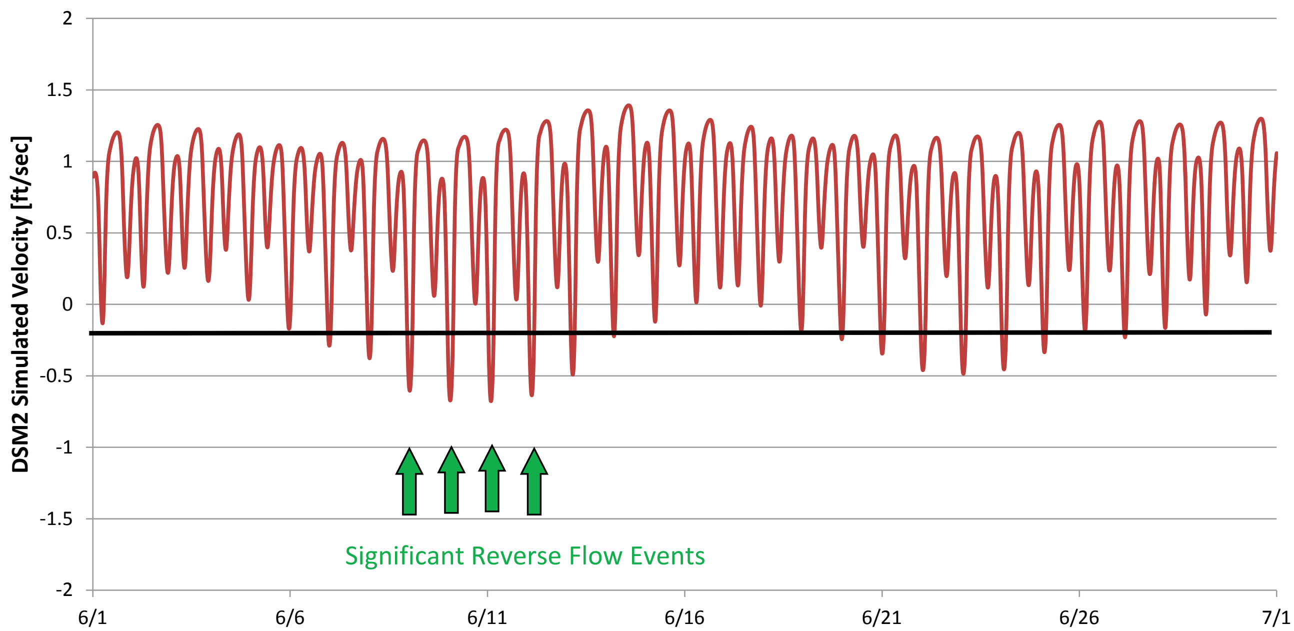
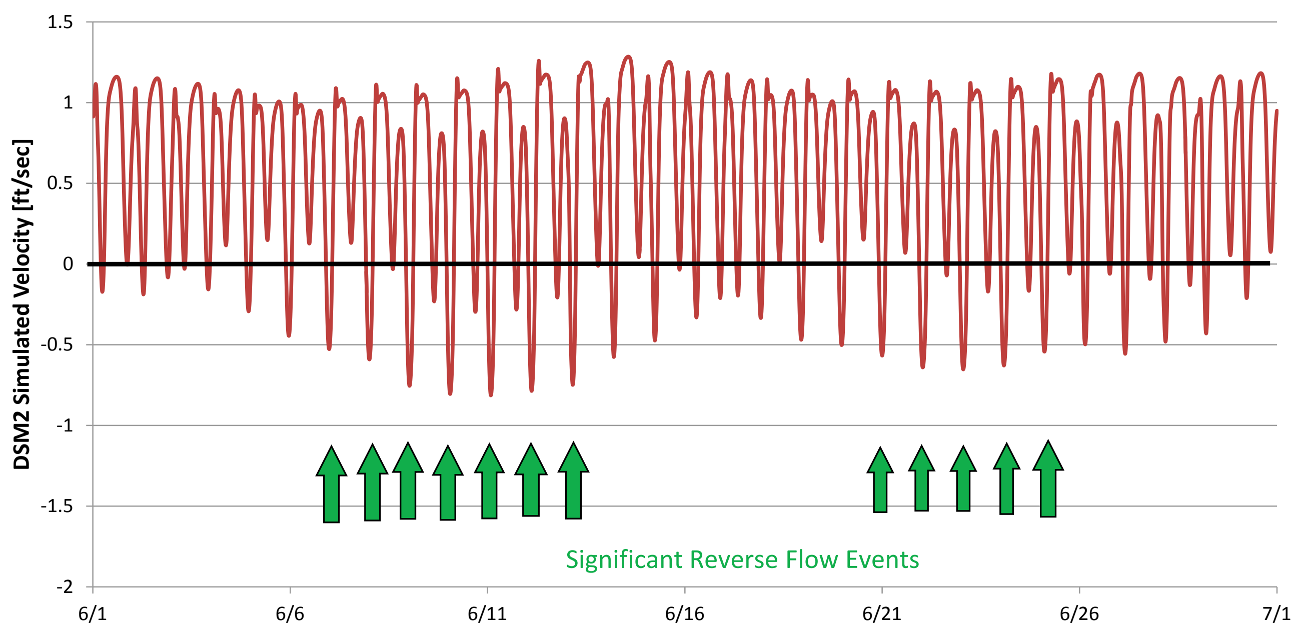


Figure 14. DSM2 Simulated Velocity at Freeport Intake, June 1990 for (a) NAA (*N*=4) and (b) Boundary 1 Project Alternative (*N*=12). Green arrows indicate significant reverse flow events which met or exceed Freeport Project intake shutdown criteria.



(a)



(b)

TABLES
1—6

Table 1. Project Effect Frequency Analysis on Low Monthly Flows at Freeport Applying the Monthly Flow Criteria (MFC). Data represents the number of months in which evaluation criteria are met.

	Project Alternative			
	H3	H4	Boundary 1	Boundary 2
1929-1934 Drought (Oct. 1928 – Oct. 1934, N = 73)	9	7	6	5
1976-1977 Drought (Oct. 1975 – Nov. 1977, N = 26)	4	4	3	4
1987-1992 Drought (Oct. 1986 – Nov. 1992, N = 74)	12	5	5	8
Drought Subtotal (N = 173)	25	16	14	17
WY 1922 – 2003 Totals (N = 984)	34	22	22	20

Table 2. Significant Reverse Flow Events for California WaterFix Water Rights Hearing Modeling Studies. Period of analysis is indicated in parenthesis.

	No Action Alternative	Project Scenario			
		H3	H4	Boundary 1	Boundary 2
1976–1977 Drought (Oct. 1975 – Oct. 1977)	31	30	33	27	28
1987–1992$^{\alpha}$ Drought (Oct. 1987 – Sep. 1990)	71	51	45	50	56
WYs 1976–1991 Total (Oct. 1975 – Sep. 1991)	113	89	86	82	96

α - Note that WY 1992 is not included in Petitioners DSM2 modeling simulation, therefore, this final year of the drought cannot be included in the analysis.

Table 3. Significant Reverse Flow Events for California WaterFix Water Rights Hearing Modeling Studies from Bias Corrected DSM2 Output. Period of analysis is indicated in parenthesis.

	No Action Alternative	Project Scenario H3	H4	Boundary 1	Boundary 2
1976–1977 Drought (Oct. 1975 – Oct. 1977)	165	183	183	160	176
1987–1992$^{\alpha}$ Drought (Sep. 1987 – Sep. 1991)	377	374	332	326	328
WYs 1976–1991 Total (Oct. 1975 – Sep. 1991)	596	572	541	500	504

α - Note that WY 1992 is not included in Petitioners DSM2 modeling simulation, therefore, this final year of the drought cannot be included in the analysis.

Table 4. DSM2 Bias Corrected Output Showing Months where Project Cases Increase the Frequency of Reverse Flow Events with Corresponding Monthly Flow Output from CalSim-II, Early Long-Term.

		Number of Significant Reverse Flow Events from DSM2					Corresponding Monthly Average Flow [cfs] from CalSim-II				
year	month	NAA	H3	H4	Bnd1	Bnd2	NAA	H3	H4	Bnd1	Bnd2
1976	11	0	9	9	9	9	9,288	7,880	7,880	7,910	7,863
		(change)	*9*	*9*	*9*	*9*		*-1,408*	*-1,408*	*-1,378*	*-1,425*
1976	12	6	16	16	16	17	8,437	7,564	7,564	7,589	7,469
		(change)	*10*	*10*	*10*	*11*		*-873*	*-873*	*-848*	*-968*
1977	7	1	0	3	0	2	8,977	9,158	8,615	9,070	8,829
		(change)	*-1*	*2*	*-1*	*1*		*181*	*-362*	*93*	*-148*
1977	9	17	37	37	38	26	6,916	6,058	6,056	6,032	6,687
		(change)	*20*	*20*	*21*	*9*		*-858*	*-860*	*-884*	*-229*
1977	10	35	43	43	20	36	6,085	5,826	5,827	6,870	6,187
		(change)	*8*	*8*	*-15*	*1*		*-259*	*-258*	*785*	*102*
1981	10	0	0	1	0	0	9,580	10,094	9,028	11,104	9,530
		(change)	*0*	*1*	*0*	*0*		*514*	*-552*	*1,524*	*-50*
1981	11	0	1	0	1	0	33,189	33,003	33,756	31,355	36,912
		(change)	*1*	*0*	*1*	*0*		*-186*	*567*	*-1,834*	*3,723*
1987	9	8	21	20	17	0	7,898	7,222	7,260	7,522	10,088
		(change)	*13*	*12*	*9*	*-8*		*-676*	*-638*	*-376*	*2,190*
1987	10	9	10	10	9	5	7,909	7,860	7,911	7,960	9,307
		(change)	*1*	*1*	*0*	*-4*		*-49*	*2*	*51*	*1,398*
1988	3	21	6	7	5	23	7,222	8,666	8,204	8,930	7,101
		(change)	*-15*	*-14*	*-16*	*2*		*1,444*	*982*	*1,708*	*-121*
1988	7	0	3	3	1	0	11,890	9,233	9,185	9,423	11,397
		(change)	*3*	*3*	*1*	*0*		*-2,657*	*-2,705*	*-2,467*	*-493*
1988	9	20	22	22	19	13	6,972	6,865	6,874	6,999	7,487
		(change)	*2*	*2*	*-1*	*-7*		*-107*	*-98*	*27*	*515*
1988	10	29	30	26	22	24	*6,326*	6,299	6,572	6,892	6,614
		(change)	*1*	*-3*	*-7*	*-5*		*-27*	*246*	*566*	*288*
1989	6	0	0	0	0	2	*13,512*	13,343	13,370	13,461	10,305
		(change)	*0*	*0*	*0*	*2*		*-169*	*-142*	*-51*	*-3,207*
1989	9	0	0	1	0	0	*14,275*	*10,365*	*9,570*	*10,336*	*12,076*
		(change)	*0*	*1*	*0*	*0*		*-3,910*	*-4,705*	*-3,939*	*-2,199*
1989	10	0	0	0	0	2	10,610	12,327	10,650	11,308	9,034
		(change)	*0*	*0*	*0*	*2*		*1,717*	*40*	*698*	*-1,576*
1989	11	10	10	10	8	12	*7,869*	*7,892*	*8,415*	*7,893*	*7,744*
		(change)	*0*	*0*	*-2*	*2*		*23*	*546*	*24*	*-125*

Table 4. cont.

year	month	Number of Significant Reverse Flow Events from DSM2					Corresponding Monthly Average Flow [cfs] from CalSim-II				
		NAA	H3	H4	Bnd1	Bnd2	NAA	H3	H4	Bnd1	Bnd2
1989	12	18	18	0	18	19	7,601	7,728	9,049	7,717	7,418
		(change)	*0*	*-18*	*0*	*1*		*127*	*1,448*	*116*	*-183*
1990	5	25	27	25	26	26	7,148	7,148	7,159	7,194	7,188
		(change)	*2*	*0*	*1*	*1*		*0*	*11*	*46*	*40*
1990	9	16	23	20	28	11	7,353	7,092	7,364	6,842	7,889
		(change)	*7*	*4*	*12*	*-5*		*-261*	*11*	*-511*	*536*
1990	10	36	38	31	18	31	6,060	6,012	6,407	6,870	6,382
		(change)	*2*	*-5*	*-18*	*-5*		*-48*	*347*	*810*	*322*
1990	12	17	18	18	3	27	7,178	7,132	7,190	9,703	6,471
		(change)	*1*	*1*	*-14*	*10*		*-46*	*12*	*2,525*	*-707*
1991	1	22	2	1	23	21	6,562	10,699	10,922	6,541	6,618
		(change)	*-20*	*-21*	*1*	*-1*		*4,137*	*4,360*	*-21*	*56*
1991	2	1	12	7	1	7	11,551	8,819	9,054	10,684	9,607
		(change)	*11*	*6*	*0*	*6*		*-2,732*	*-2,497*	*-867*	*-1,944*
1991	3	0	1	1	0	0	26,936	27,099	27,116	27,147	27,040
		(change)	*1*	*1*	*0*	*0*		*163*	*180*	*211*	*104*
1991	4	2	3	3	2	3	12,276	12,295	12,314	12,323	12,256
		(change)	*1*	*1*	*0*	*1*		*19*	*38*	*47*	*-20*
1991	6	4	10	10	12	10	9,694	8,292	8,303	8,107	8,217
		(change)	*6*	*6*	*8*	*6*		*-1,402*	*-1,391*	*-1,587*	*-1,477*
1991	7	0	2	0	2	0	12,770	9,292	9,367	9,126	11,468
		(change)	*2*	*0*	*2*	*0*		*-3,478*	*-3,403*	*-3,644*	*-1,302*
1991	8	0	14	14	14	0	8,925	7,833	7,856	7,803	9,584
		(change)	*14*	*14*	*14*	*0*		*-1,092*	*-1,069*	*-1,122*	*659*

For ease of reference, increases in significant reverse flow events and corresponding monthly flows are colored with red font. Decreases in significant reverse flow events and corresponding monthly flows are colored with green font. For cases where there is no change in the number of significant reverse flow events, grey font is used. Also, *italicized* font is used for each "change" row of the table where the NAA is subtracted from the project alternative.

Table 5. Significant Reverse Flow Analysis of BDCP Project Simulations Excerpted from page 171 of EBMUD's Comment Letter to the BDCP Dated July 28, 2014. Note period simulated with DSM2 is October 1975 through September 1991 i.e. Water Years 1976 through 1991.

Table 3: Reverse Flow Events with Advective Transport Exceeding 0.9 Miles for DWR Modeling Studies, 1974-1991 Hydrology.

Model Study	Brief Description	Number of Events
EX_ROA0_SLR0_CC0	Existing Case, Includes Fall X2	25
EX_No_FallX2_ROA0_SLR0_CC0	Existing Case, No Fall X2	30
NAA_ELT_ROA0_SLR15_CC5	No Action Case, Early	70
NAA_LLT_ROA0_SLR45_CC5	No Action Case, Late	178
NAA_ROA0_SLR0_CC0	No Action Case, General	22
ALT4_ELT_ROA25_SLR15_CC5	Action Case, Early	14
ALT4_LLT_ROA65_SLR45_CC5	Action Case, Late	21

Table 6. Independent Outside Modeling of NAA and Project Alternative 4A with and without Tidal-Marsh Restoration Excerpted from page 172 of EBMUD's Comment Letter to the BDCP Dated July 28, 2014. Note period simulated with DSM2 is October 1921 through September 2003 *i.e.* Water Years 1922 through 2003 where results for the shorter 16-year period simulated by DWR is also provided for reference. With deactivation of assumptions for climate change (CC) and sealevel rise (SLR), the time basis for the modeling scenarios is rendered moot, hence no indication of the ELT or LLT timeframe.

Table 4: Reverse Flow Events with Advective Transport Exceeding 0.9 Miles for MBK Modeling Studies, 1921-2003 Hydrology and 1974-1991 Hydrology.

Model Study	Brief Description	Number of Events 1921-2003 Hydrology	Number of Events 1974-1991 Hydrology
MBK_FutBase_CC0_SLR0	Base Case	203	55
MBK_BDCP_ALT4_CC0_SLR0_ROA0	Action Case	237	64
MBK_FutBase_CC0_SLR0_ROA25	Base Case with Restoration	49	11
MBK_BDCP_ALT4_CC0_SLR0_ROA25	Action Case with Restoration	55	12