Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

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Chapter 3
Estimating the Impact of Groundwater on Delta Channel Depletions

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3.1 Background

3.1.1 Delta Channel Depletion Relates to Model EC in the Summers of Critical and Dry Years.

Historical Delta electric conductivity (EC) during critical and dry years, simulated by Delta Simulation Model 2 (DSM2), has been investigated since DSM2 was developed in the 1990s. In the 2006 Annual Report, Myint Thein and Parviz Nader-Tehrani noted large discrepancies between observed and DSM2-simulated EC during summers of dry periods, 1975-1989. Similar accuracy concerns of modeled EC have been noted during drought years after 1989. Figure 3-1 shows the Delta Island Consumptive Use (DICU)-based DSM2-simulated EC and the observed EC in the Delta confluence area during the critical years, 1990 and 1991. DSM2-DETAW-wo-CD, Delta Evapotranspiration of Applied Water without groundwater assumption, is also shown in Figure 3-1 and will be explained in more detail later in this chapter.

The EC estimation in the west Delta is strongly related to Delta outflow. Low Delta outflow for a sufficiently long duration will cause salinity intrusion, while high Delta outflow will eventually push salinity out of the Delta. Calculated Delta outflow is the total Delta inflow less exports and channel depletions. Errors in modeled historical channel depletions will result in errors in modeled Delta outflow, which, in turn, cause errors in the modeled extent of seawater intrusion. Potential errors in modeled salinity intrusion are highly sensitive to Delta outflow. When Delta outflow is low, particularly over an extended period, the simulated location of high salinity gradient in the west Delta can vary widely for relatively small changes in estimated outflow. The significant overestimation of DSM2-modeled historical EC in critical and dry years is most likely the result of overestimating channel depletions. Sufficiently accurate estimations of Delta channel depletion are crucial to producing meaningful DSM2 simulations of salinity intrusion when the Delta outflow is low.

3.1.2 Existing Problems in Modeling Delta Channel Depletion

Delta island consumptive use is the island water lost mostly because of crop evapotranspiration (ET). Related to consumptive use, Delta channel depletion is the water gained or lost in the Delta channels. The consumptive-use models, such as DICU and Delta Evapotranspiration of Applied Water (DETAW), estimate crop ET on Delta islands and the water sources to supply the water demands. These water sources include rainfall, seepage, and applied water. To model Delta hydrodynamics and water quality, DICU has a post-processing computer program that computes the channel depletion, based on the assumptions representing the correlations between the water sources and the channel depletion. DETAW does not have this post-processing program.

In the initial phase of implementing DETAW for the Delta, the same assumptions used with DICU were applied to take estimated island consumptive use and generate channel depletion. Similar to the DICU-based DSM2 simulation, the DETAW-based DSM2 simulation of EC generated considerably higher EC than the observed data in the critical years (Figure 3-1). Attempting to improve the DSM2 simulation of EC during extended low outflow periods, the allocation of sources of water to meet Delta consumptive use was reexamined.

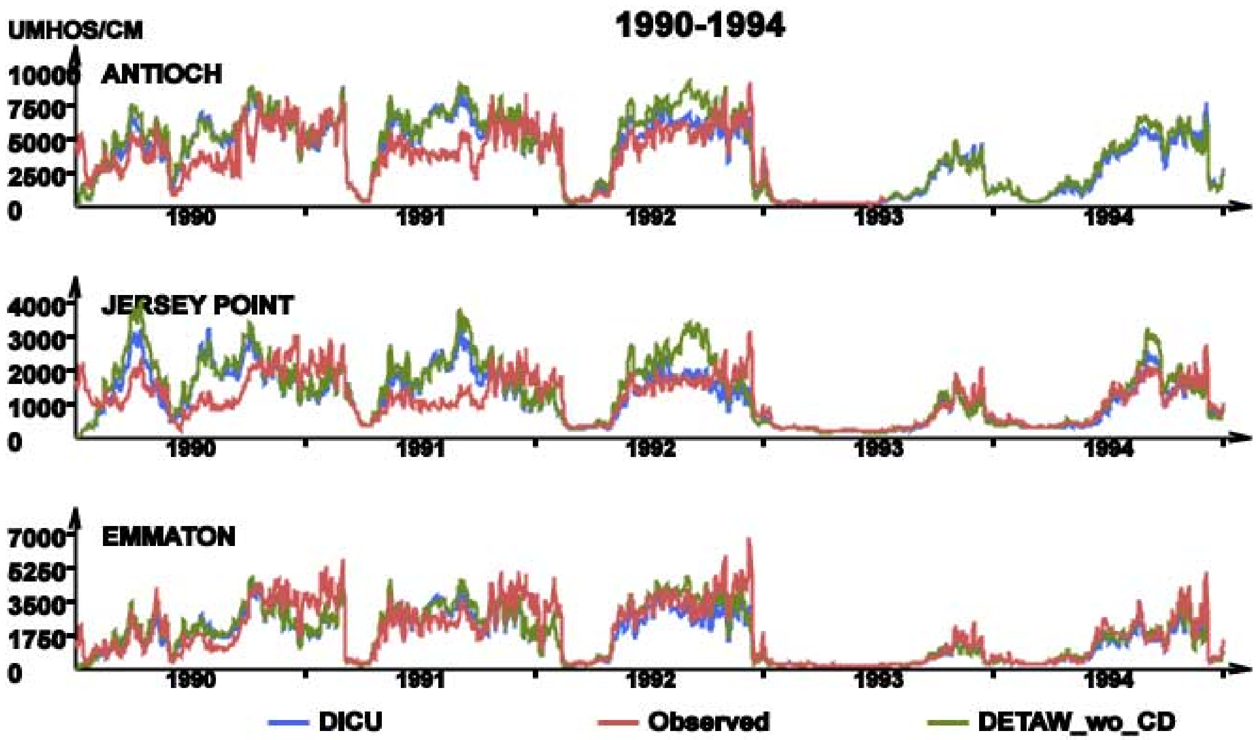

Figure 3-1 Examples of EC Comparison of DSM2-DICU, DSM2-DETAW-wo-CD and Observation

3.2 Literature Review

A literature review was conducted to explore past assumptions and study conclusions of the water sources that contributed to meeting the island consumptive use demands. The findings are described in the following two sections.

3.2.1 Delta Uplands Findings

The *Draft Environmental Impact Report/Environmental Impact Statement Bay Delta Conservation Plan* (California Department of Water Resources 2013) summarizes the domestic and irrigation wells in the Delta and indicates there are at least 3,693 domestic wells and 420 municipal and irrigation wells in the Delta. Although the actual pumping yield is unknown, the amount of wells proves that some groundwater is pumped for irrigation and urban use.

In addition, the California Department of Water Resources (DWR) North Central Region Office maintains a database of the groundwater wells in the Delta. Projecting the well locations on a geographic information system map indicates that most wells are located in Delta Uplands.

3.2.2 Delta Lowlands Findings

A basic assumption of using island consumptive use to calculate the channel depletion in DICU and DETAW is that the channel water is the sole water source to meet demands in the Delta, excluding precipitation and soil moisture. Nonetheless, a literature review revealed that groundwater is a significant source of water in the Delta. From 1956 to 1959, DWR published four reports about the investigation of groundwater in the Sacramento-San Joaquin Delta. Reports No. 2 (Kabakov et al. 1956b) and No. 3 (Kabakov et al. 1959) found that applied water on Medford and McDonald islands was composed of approximately 80 percent of San Joaquin River and 20 percent of Mokelumne River area groundwater and connate water.

It is apparent that the estimation of the Delta channel depletion should be modified by including groundwater as a source to meet island water demands.

3.3 DETAW-CD Methodology

Since DETAW has been developed to replace DICU to estimate consumptive use in the Delta, DETAW now also accounts for groundwater in calculating Delta channel depletions. Using this new post-processing, DETAW-Produced Channel Depletion (DETAW-CD), simulates not only the water interactions between channels and ground surface, but also those interactions between groundwater and ground surface. Three water interactions between groundwater and ground surface have been added in DETAW-CD. These are the groundwater pumping for the Delta Uplands irrigation, groundwater interaction with ground surface in the Delta Lowlands, and deep percolation.

3.3.1 Groundwater for Delta Uplands Irrigation

The groundwater contribution is assumed to be a constant fraction of the applied water. The groundwater rate of each year is determined based on the accumulated number of irrigation wells of that year. The annual number of irrigation wells from the 1940s to the present was obtained from the groundwater well database maintained by the DWR North Central Region Office. No irrigation wells were recorded before the 1950s, so the groundwater rate in the Delta Uplands then was assumed to be zero. After 1950, the rate gradually increased as the number of recorded wells increased. In 2009 and later, the portion of consumptive-use demands met by groundwater in Delta Uplands is set at 40 percent.

3.3.2 Groundwater for Delta Lowlands Irrigation

Based on the studies of the chemical makeup of agricultural drainage, which DWR conducted in the 1950s, the main water supply to two islands in the Delta lowlands — Medford and McDonald islands — consisted of 20 percent groundwater from the areas surrounding the Delta and the connate water, and 80 percent from channel surface water. Due to the significant subsidence in the Delta Lowlands since that time, it is assumed that the groundwater in the past several decades contributed more to the island consumptive use. The portion of consumptive-use demands met by groundwater in the Delta Lowlands is set at 25 percent for all years.

3.3.3 Deep Percolation

In the new implementation of DETAW-CD, deep percolation of precipitation is assumed to be 25 percent of the residue of the precipitation after supplying the evapotranspiration.

3.4 Impacts of Incorporating Groundwater on Channel Depletion, Delta Outflow, and EC Modeling

3.4.1 Impact on Channel Depletion

Figure 3-2 presents the average monthly Delta channel depletion from water year (WY) 1975 to WY 2010 by different consumptive-use models: DICU, DETAW-wo-CD, and DETAW-CD. DETAW-wo-CD represents DETAW without the groundwater assumption. DETAW-CD generates lower channel depletion than DICU because of groundwater supply. The difference between the DETAW-wo-CD and DETAW-CD for each month is the amount of groundwater supply. The groundwater contribution in spring and summer is driven by the consumptive use, so it varies in a similar pattern like the consumptive use does. The maximum average groundwater supply is about 1,500 cubic feet per second (cfs) in July.

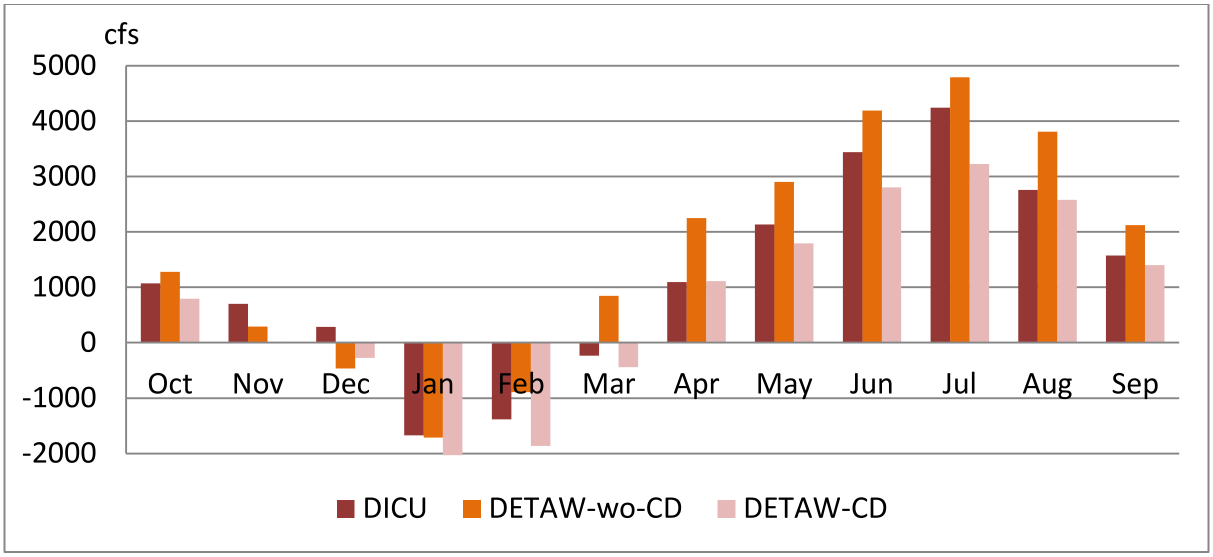

Figure 3-2 Average Monthly Delta Channel Depletion from WY 1975 to WY 2010

3.4.2 Impact on Net Delta Outflow (NDO)

Since the channel depletion of DETAW-CD is less than that of DICU and DETAW-wo-CD, the net Delta outflow (NDO) of DETAW-CD is higher than for the other models. Figure 3-3 compares monthly average NDO by DICU, DAYFLOW, DETAW-wo-CD, and DETAW-CD when DICU NDOs are less than 6,000 cfs. Salinity intrusion under these low outflows is sensitive to small changes in NDO. DICU, DAYFLOW, and DETAW-wo-CD produced more or less similar NDOs, but DETAW-CD generally has a higher NDO than other models.

3.4.3 Impact on EC Simulation

Simulated historical EC for models DSM2-DICU and DSM2-DETAW-CD are shown in Figure 3-4, along with the Interagency Ecological Program (IEP) observed data. The models DSM2-DICU and DSM2-DETAW-CD use the same DSM2 setup, but with different channel depletions. With the consideration of groundwater, the EC simulation matches well with the field data. Most of the large EC overestimations by DICU and DETAW-wo-CD shown in Figure 3-1 have been eliminated.

Nonetheless, the discrepancies between DETAW-CD and the field data for some fall and winter periods still exist. During the transition period from the irrigation season to the nonirrigation season, the groundwater interaction with the ground surface in the Delta is probably related to many random farming activities and water environment variation, and both are hard to predict.

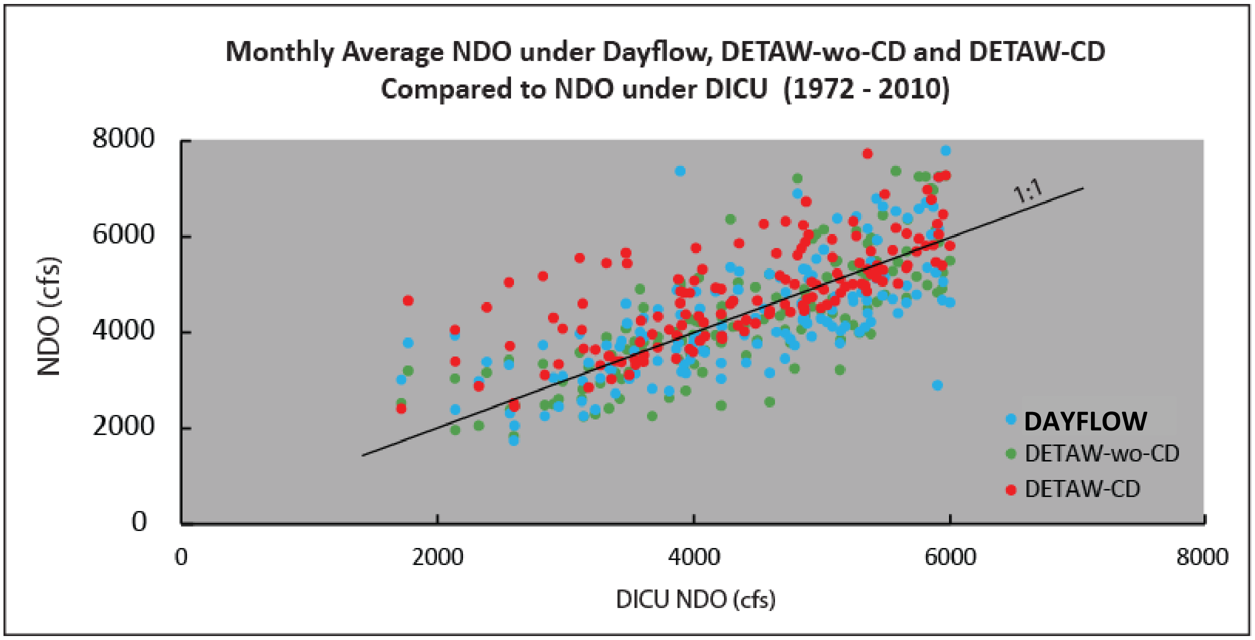

Figure 3-3 Monthly Average NDO under DAYFLOW, DETAW-wo-CD, and DETAW-CD Compared with DICU

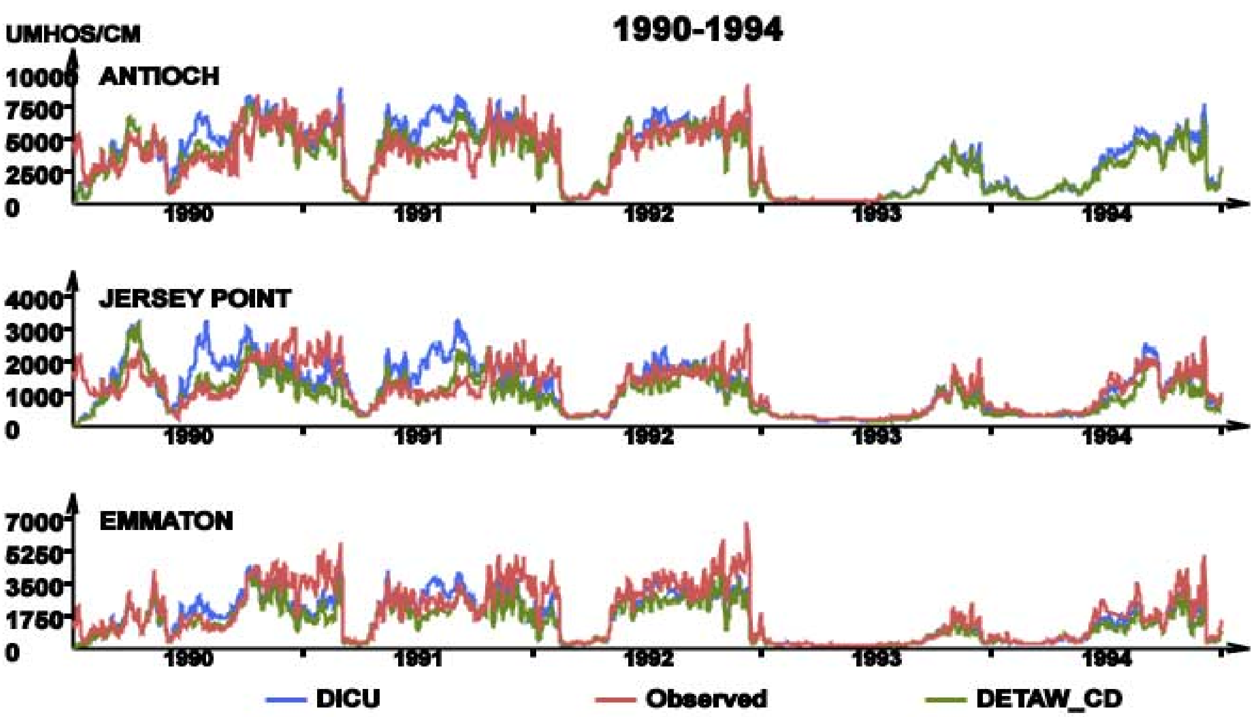

Figure 3-4 EC Comparisons of DSM2-DICU, DSM2-DETAW-CD, and the Observed Data from IEP

3.5 Conclusion

Although the concept of groundwater contributing to the Delta consumptive use has been recognized in the past, the quantifying of groundwater supply is still at the starting point. This study integrated consumptive use, hydrodynamics, and water quality models, and then calibrated the groundwater supply and EC together by using the correlations between Delta outflow and EC. With the estimated groundwater contribution, EC in the summers of the critical and dry years can be estimated to be close to the measured field data. Nonetheless, factors contributing to EC during the transition period from irrigation season to nonirrigation season seem more random. More data describing the flow interactions among channels, groundwater, and ground surface during those periods should help further understand the Delta groundwater supply.

3.6 References

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