Relationships between Water Quality Constituents in the Delta and the Influence of Different Sources of Water

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Introduction

Delta salinity is typically measured (or modeled) as specific electrical conductance (EC). However, drinking water and other beneficial uses are often considered in terms of other constituents such as chloride, bromide, sodium, and total dissolved solids. Historical water quality grab samples collected from the Sacramento-San Joaquin Delta by DWR, the U.S. Bureau of Reclamation, and other agencies since the 1950s have been used to develop conversion relationships between key indicators of salinity (EC, TDS) and other water quality constituents such as calcium, and sulfate (Figure 1). These conversion relationships vary spatially throughout the Delta depending on the site-specific contributions from seawater intrusion, San Joaquin inflow or other sources of water. This work builds upon previous work by Suits (2002). The site-specific contributions to EC from these different water sources vary by water year type and season, but can be quantified as a function of salinity in the western Delta which is strongly dependent on Delta outflow.

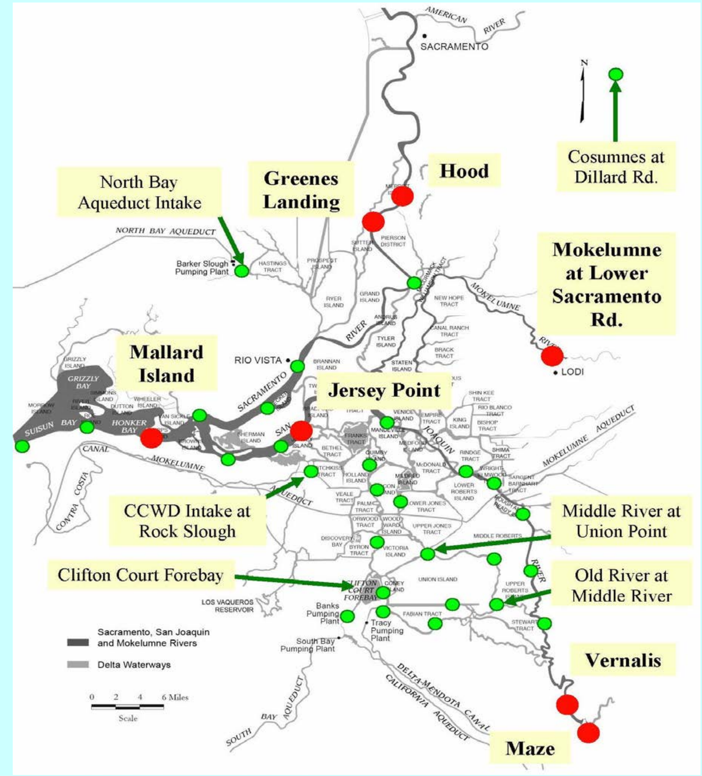

Figure 1: Map of the Sacramento-San Joaquin Delta system showing the locations of the key boundary condition stations (large red dots) and other monitoring stations.

Regression equations were developed by plotting grab sample water quality data as a function of EC or total dissolved solids (TDS). The water quality constituents (chloride, bromide, sodium, calcium, sulfate) are generally highly correlated (r-squared > 0.8) and for interior Delta stations where the range of salinity is relatively low (EC < 1,200 µS/cm), the relationships are generally linear, i.e.,

$$Y = bX + c \quad \text{.......} \quad (1)$$

where Y is the water quality constituent, X is either EC or TDS, and b and c are the coefficients used to fit the available grab sample data.

At the western Delta and Suisun and San Pablo Bay stations, grab sample salinities were much higher (EC < 20,000 µS/cm) due to a high level of seawater intrusion. In those cases, a quadratic equation was found to be more suitable, i.e.,

$$Y = aX^2 + bX + c \quad \text{.......} \quad (2)$$

where a, b and c are three regression fit coefficients.

The least-squares quadratic or linear regressions (e.g., using Excel) do not always agree with the data over the full range of EC and TDS. The quadratic regression fit for Mallard Island data in Suisun Bay (EC up to 19,000 µS/cm) has an r-squared of 0.991. However, the agreement between the regression fit and data for EC < 1,200 µS/cm, representing typical Delta salinity conditions with the interior Delta is poor (Figure 2).

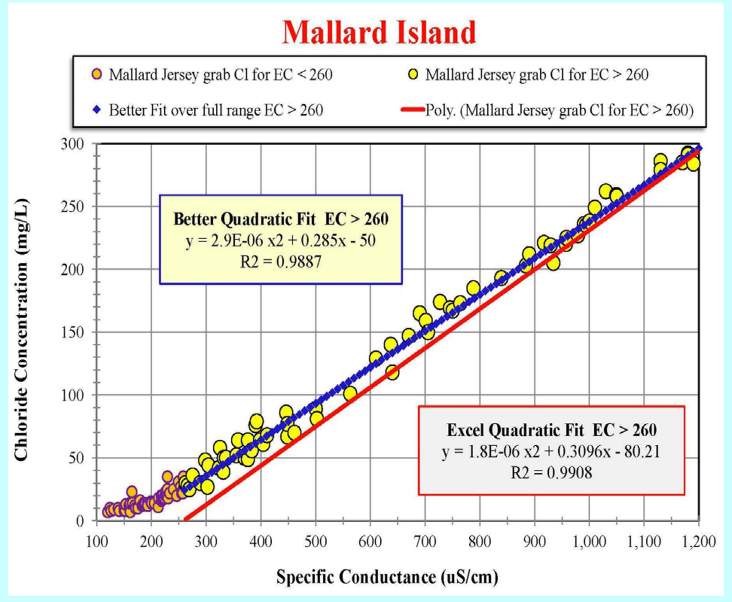

Figure 2: Chloride concentration (Cl) as a function of specific conductance (EC) for Mallard Island and Jersey Point grab samples for EC < 1,200 µS/cm) generally experienced in the south and central Delta. A different quadratic equation (with zero intercept) is needed to fit the data for EC < 260 µS/cm.

During high Delta outflow events, the salinities at Mallard Island are very low (EC < 260 µS/cm) and water quality is dominated by freshwater flow mixed with some agricultural drainage. A different regression equation (quadratic with zero intercept) was used to fit the grab sample data over this low EC range.

Another major source of salinity in the Delta is agricultural drainage from the San Joaquin Valley (as measured at Vernalis and Maze).

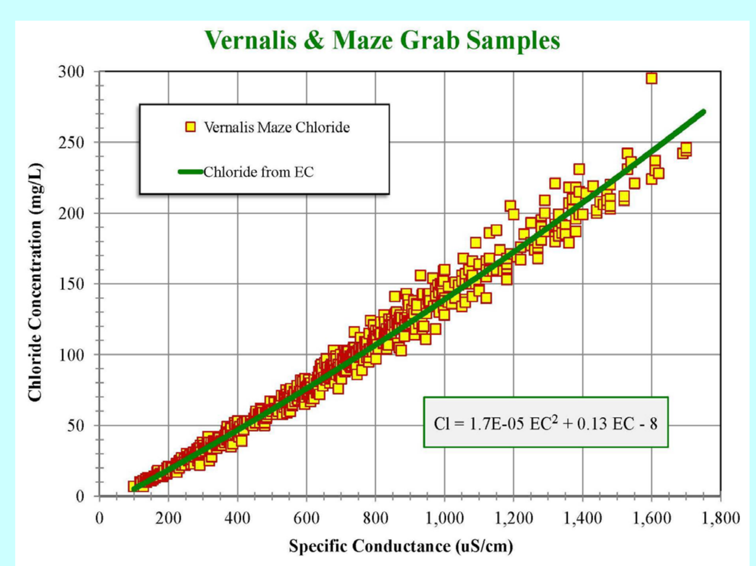

Figure 3: Variation of chloride concentration with specific conductance (EC) for grab samples for the San Joaquin River at Vernalis and Maze.

Application to Interior Delta Stations

The boundary condition equations for seawater intrusion and agricultural drainage from the San Joaquin River represent the upper and lower bounds on the data, respectively (Figure 4). When the water locally is a mixture of both sources, the water quality represents the sum of both contributions. In the case of sulfate concentration, seawater intrusion then represents the lower bound (Figure 5).

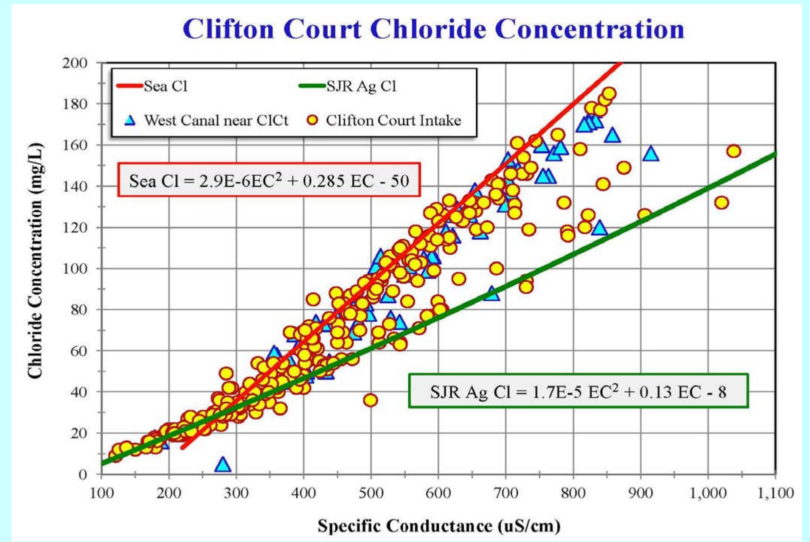

Figure 4: Variation of chloride concentration as a function of specific conductance at the intake to Clifton Court Forebay.

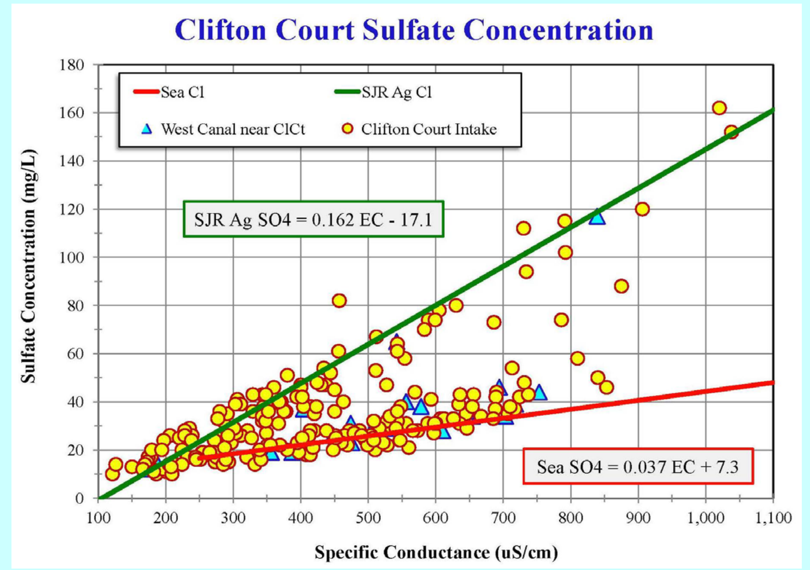

Figure 5: Variation of sulfate concentration as a function of specific conductance at the intake to Clifton Court Forebay.

Estimating Contribution to EC from Seawater Intrusion

Jersey Point EC data are typically available from continuous field measurements of EC. Where there are gaps, the Jersey Point EC can be estimated from DAYFLOW Delta outflow estimates using a salinity-outflow relationship like CCWD's G-Model (Denton, 1993). The correlation between Jersey Point EC and continuous total EC from a given Delta location is used to estimate the local contribution from seawater (Figure 6).

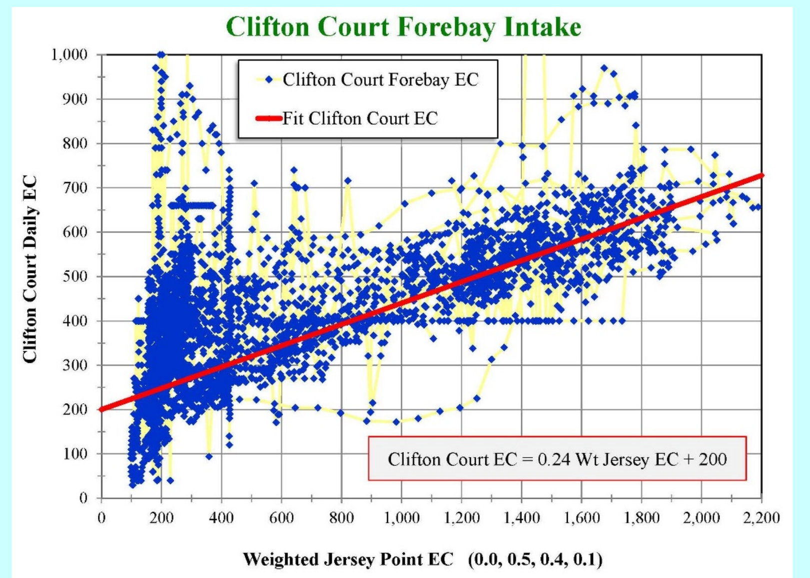

Figure 6: Comparison of the entrance to Clifton Court Forebay EC with weighted Jersey Point EC (1964-2012 data). The seawater-dominated relationship (red line) can be used to estimate the seawater contribution at Clifton Court.

From 2000-2003, seawater made a major contribution to the EC at Clifton Court Forebay from August through December. For the rest of each year, agricultural drainage from the San Joaquin River and local Delta sources dominated (Figure 7).

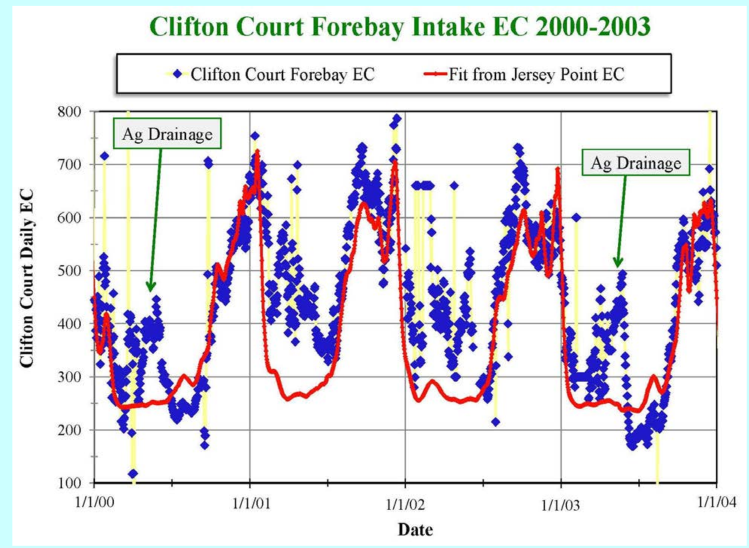

Figure 7: Comparison of estimated Clifton Court EC due to seawater intrusion with measured EC data (2000 – 2003).

*Note that the estimate from Jersey Point EC includes a background amount of agricultural drainage (≈ 250 µS/cm). The actual **seawater contribution** is effectively zero from January-July.*

Conclusions

- The relationships between different water quality constituents and EC (or TDS) in the south and central Delta depend upon the particular mixture of seawater and agricultural drainage from the San Joaquin River and Delta islands.
- Seawater intrusion generally dominates in the late summer and fall, except in very wet years. In critical years, Delta outflows can remain low throughout the year extending the period when seawater intrusion occurs.
- The contribution of seawater to interior Delta water quality can be estimated from the salinity at Jersey Point in the western Delta.
- Once the contribution by seawater intrusion to total EC is determined, the seawater EC can be converted to a given water quality constituent using the seawater equation and the remaining EC converted using the agricultural drainage equation.
- This approach works for field data as well as water quality modeling output (e.g., DWR's DSM2 model).
- The percentage contribution to EC from seawater can also be estimated based on the month of the year and Sacramento 40-30-30 water year index.

References

Denton, Richard A. (1993), *Accounting for Antecedent Conditions in Seawater Intrusion Modeling - Applications for the San Francisco Bay-Delta.* Hydraulic Engineering 93, Volume 1, pp. 448-453, Proceedings of ASCE National Conference on Hydraulic Engineering, San Francisco, July 1993.

Suits, Bob (2002), *Chapter 5, Relationships between Delta Water Quality Constituents as derived from Grab Samples.* In DWR's *"Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh."* 23rd Annual Progress Report, June 2002. http://modeling.water.ca.gov/delta/reports/annrpt/2002/2002Ch5.pdf

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