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

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Chapter 5: Relationships between Delta Water Quality Constituents as Derived from Grab Samples

Author: Bob Suits

5 Relationships between Delta Water Quality Constituents as Derived from Grab Samples

5.1 Introduction

Delta grab samples are being analyzed to establish relationships between various water quality constituents. Wherever justified, relationships are developed for discrete regions rather than for individual locations. The purpose of this study is to replace published Delta relationships between total dissolved solids (TDS), chloride, and electrical conductivity (EC); provide insight into some characteristics of the mixing of Delta water; and to provide another basis for validating DSM2-QUAL. This chapter presents a brief background and methodology for this ongoing project.

5.2 General Methodology

Relationships between Delta water quality constituents are routinely developed to support Delta modeling activities. One recent example was developing relationships between EC and chloride at export locations in order to check model results that were in EC against water quality standards in chloride. Often the only source of data available to do such analysis is historic grab samples. Grab samples, collected by various programs, will usually be analyzed for multiple constituents, most commonly EC, TDS, and chloride. However, many other constituents may also be evaluated, depending upon the purpose of the monitoring. The last time DWR conducted a Delta-wide evaluation of multiple relationships derived from grab sample data was presented in a 1986 Department memo (Guivetchi, 1986). This analysis was a compilation of regressions generated between EC and chloride, EC and TDS, and chloride and TDS. Thirty-four locations in the Bay-Delta system were independently examined and relationships were broken down by water year type (dry years, normal years, wet years, and all years), with water year classification being defined according to State Water Resources Quality Control Board Decision 1485 (D-1485).

The current project differs from the previous study in several ways. First, the scope of the analysis is substantially larger. Previously, only samples collected by U.S. Bureau of Reclamation and DWR from 1968 through 1981 as part of the D-1485 monitoring program were used, and only TDS, chloride, and EC were evaluated. The current project expands the data used to include grab samples collected by DWR's Operations and Maintenance (O&M) and Municipal Water Quality Investigations (MWQI), and draws upon data through 1999. Data from the now-defunct Water Information Monitoring System (WIMS) are also considered. WIMS data come from a variety of mostly undocumented sources and date back to 1955. The use of WIMS data in this project is relatively limited and more recent data from the other three sources are given precedence.

The current project also expands the number of constituents evaluated. In addition to finding relationships among EC, chloride, and TDS, the project will also add calcium, sulfate, potassium, magnesium, sodium, and bromide to the list of constituents to be evaluated. Table 5.1 summarizes the amount of data available for the analysis. The data are stored in ACCESS and flagged for redundancy and obvious error. Delta inflow and export values from DAYFLOW, also stored in the database, allow ACCESS queries to return pairs of constituent values and daily average Delta inflows and exports.

Table 5.1: Summary of Data Count for Analysis.

Constituent	D-1485	MWQI	WIMS	O & M	TOTAL
Calcium	0	1521	3047	606	5174
EC	10948	1920	7598	903	21369
CL	8362	1919	8760	895	19936
TDS	6702	998	4676	837	13213
Na	0	1910	5921	875	8706
SO4	0	0	2136	828	2964
Br	0	1430	1	153	1584
K	0	1194	2824	159	4177
Mg	0	1521	3385	607	5513
ALK	0	995	6325	247	7567
TOTAL	26584	13408	44673	6110	90775

The present study's focus is different from the 1986 effort. Previously, relationships between EC, TDS, and chloride were presented for 34 locations and were broken down by water year classification. This approach had two shortcomings. First, the 1986 analysis' breakdown of regression by water year type is misleading. Since the relationship between constituents may be different for different sources of water and different flow patterns result in different mixing, it is reasonable to attempt to associate relationships between water quality constituents at any location in the Delta with Delta flow conditions. However, using the water year type as a surrogate for Delta flow conditions is over-simplistic. Second, the 1986 analysis fails to generalize Delta mixing characteristics by region.

In comparison, the current study does not differentiate relationships by water year type, rather it attempts to identify regions within the Delta that may be described by a single relationship between any two constituents. Trends in patterns of mixing of source water might hopefully then be inferred. Also, regional relationships should provide an additional source for validation of DSM2-QUAL. The extent that QUAL produces patterns of relationships between modeled constituents that are consistent with those derived from observed historic grab samples should indicate how well QUAL simulates the gross mixing of Delta water. Finally, because the focus of this study is analysis to support evaluating DSM2, only regions within DSM2's boundaries are being considered.

5.3 Methodology

Grab data compiled from the sources mentioned above have been screened to include only surface water samples (depth of 4 feet or less). At any one site, most data was sampled monthly. When more frequent sampling occurred, the data was screened to maintain a minimum of 10 days between samples. In areas of the Delta where flows and subsequent mixing of water may be affected by SWP exports, only data after 1971 was used, effectively eliminating the use of WIMS data from Old River. The purpose of this study is to identify mixing patterns of water under conditions that DSM2 will simulate for validation purposes. Thus, evaluating pre-SWP conditions for this study is beyond the scope of the project. A separate analysis is underway examining if the relationships between water quality constituents, and thus perhaps mixing patterns, have changed since SWP operations in the Delta began. For any pair of constituents, a separate regression is found for regions as close as possible to a DSM2 boundary: in the west Delta starting at Carquinez Strait at Martinez and moving west, in the San Joaquin River starting at Vernalis and moving downstream, and in the Sacramento River starting at Sacramento and moving downstream. At each boundary location, data from adjacent sites are incrementally added as long as the data are judged to display the same relationship. A single regression is eventually developed for each grouping of sample sites.

Other sites within the Delta are grouped according to the consistent relationships between the pair of constituents and then compared for reference to the regressions for the boundary groups. For any pair of constituents, the San Joaquin River group and the Sacramento River group usually display similar but different relationships, while the west Delta group may also be similar or radically different, depending upon the particular constituents. The relationship between the constituents at interior Delta locations can typically be described in approximately 12 discrete regions.

5.4 A Sample Analysis

As an example of the procedure described above, a preliminary analysis with chloride and calcium is presented. This particular analysis is illustrative in that chloride and calcium sampling can effectively reveal mixing trends in the Delta; certain regions in the Delta display a predictable mixing while others reveal a complexity that will require DSM2 modeling to understand. Fresh waters such as Delta inflows from rivers and streams tend to have a relatively high portion of TDS from calcium and less from chloride, thus the ratio of calcium to chloride is typically high (2 to 3 in the Sacramento and San Joaquin rivers). For ocean water, on the other hand, much more of TDS comes from chloride and the calcium to chloride ratio is low, typically around 0.02. Therefore, Delta water samples will reveal ratios of calcium to chloride ranging between 0.02 to 3, depending upon the mixing of the sources of the constituents.

Figure 5.1 shows where the data is available for these constituents. Also shown is how the west Delta, Sacramento River, and San Joaquin River groups are formed, as well as the interior regions. Table 5.2 describes the data available for the analysis. Figure 5.2 shows the relationships between chloride and calcium for the San Joaquin River and west Delta regions and Figure 5.3 shows the relationships in the Contra Costa Canal and Franks Tract regions.
Table 5.3 presents the regressions shown in these figures.

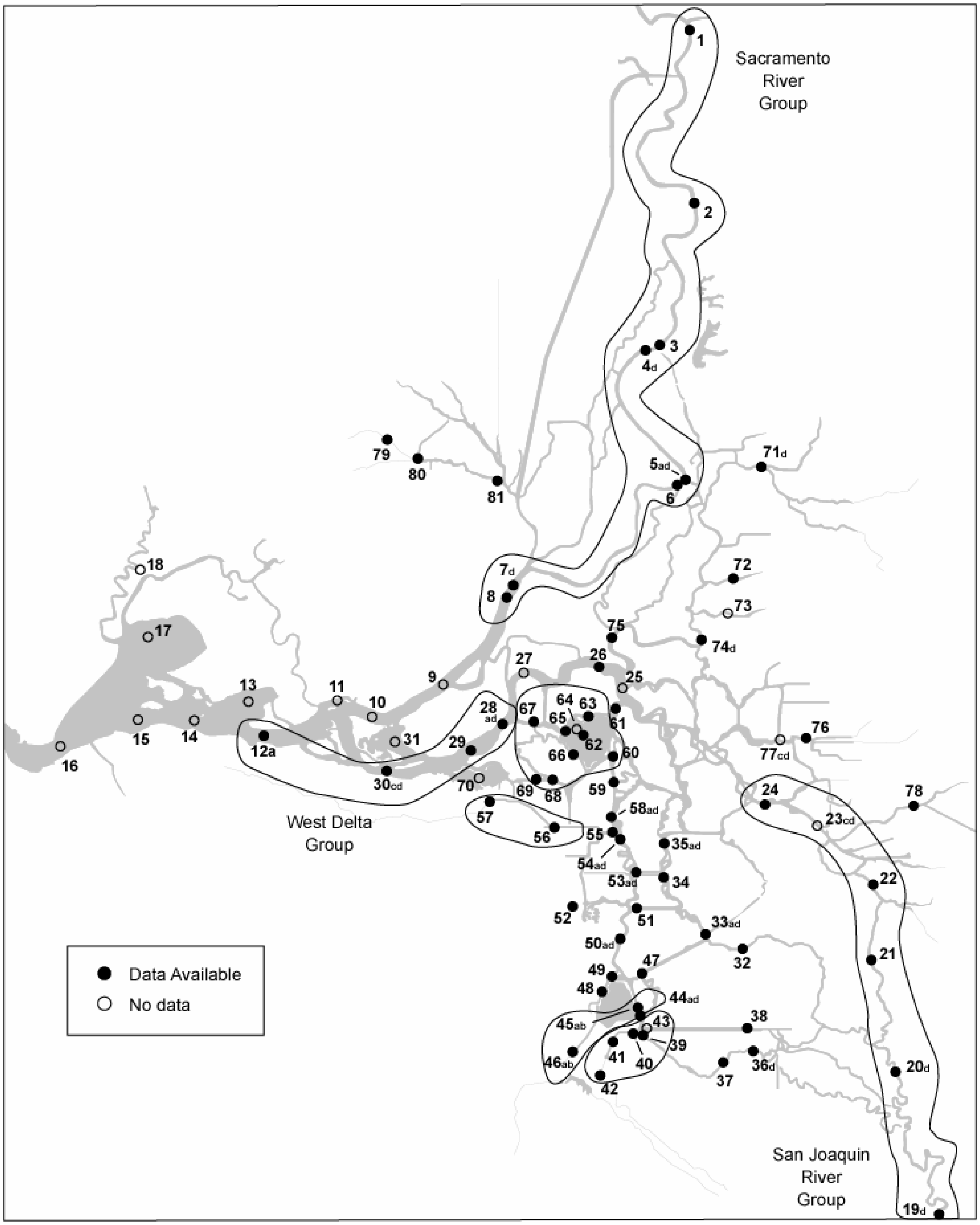


Figure 5.1: Locations of Available Data and Sample Groupings for Chloride and Calcium Analysis.

Table 5.2: Summary of Data Available for Analysis of Chloride and Calcium Relationships.

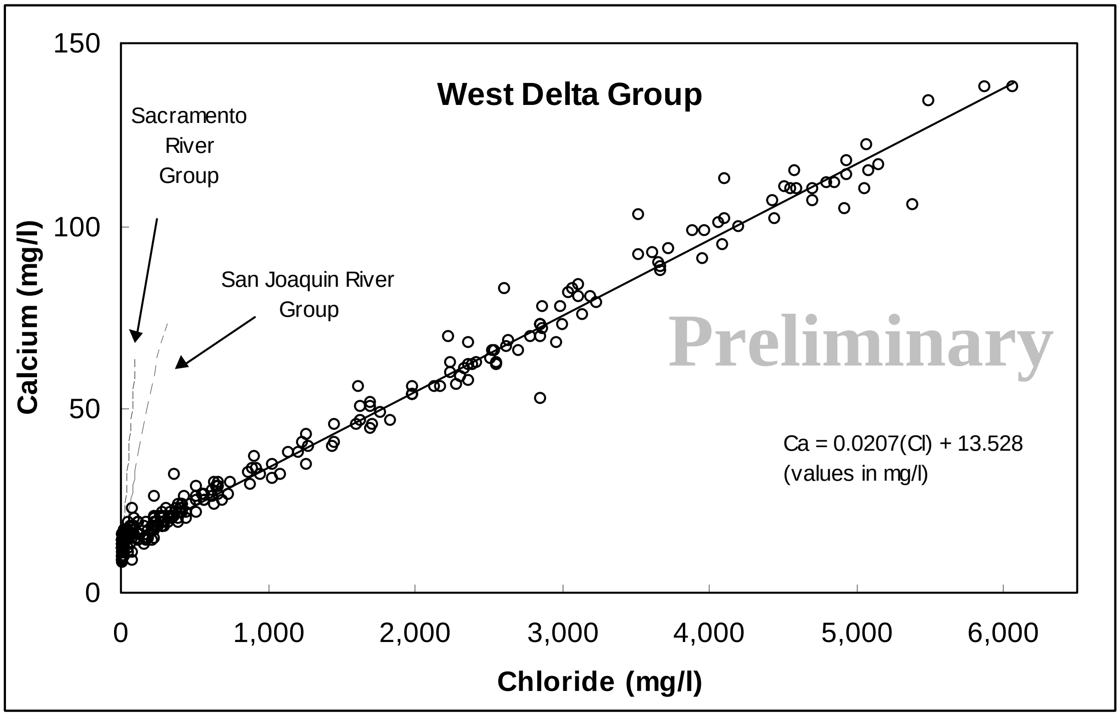
Preliminary

Site	Description	Source	# samples	Chloride (mg/L) Min	Chloride (mg/L) Max	Chloride (mg/L) Avg	Calcium (mg/L) Min	Calcium (mg/L) Max	Calcium (mg/L) Avg
1	Sacramento River at Sacramento	WIMS	38	1	13	5	5	17	11
2	Sacramento River at Freeport	WIMS	65	2	15	6	7	18	12
3	Sacramento River at Snodgrass Slough	WIMS	103	1	23	9	4	25	13
4 d	Sacramento River at Greens Landing	WIMS	156	2	14	6	6	16	11
5 a	Delta Cross Channel at west end	MWQI	21	1	12	7	8	16	12
5 d	Delta Cross Channel at west end	WIMS	41	1	17	8	6	18	12
6	Sacramento River at Walnut Grove	WIMS	46	3	16	8	7	17	12
7 d	Sacramento River at Rio Vista	WIMS	15	4	13	9	10	18	14
8	Sacramento River at Rio Vista	WIMS	[illegible]	[illegible]	15	8	9	88	16
12 a	Sacramento River at Chipps Island	MWQI	143	7	6060	2182	8	138	58
19 d	San Joaquin River near Vernalis	WIMS	186	6	312	115	7	75	35
20 d	San Joaquin River at Mossdale	WIMS	162	6	307	129	8	82	39
21	San Joaquin River at Brandt Bridge	WIMS	104	14	195	79	8	50	28
22	San Joaquin River at Highway 4	WIMS	40	11	182	92	8	54	30
24	San Joaquin River at Rindge Tract	WIMS	40	14	152	68	10	50	24
26	San Joaquin River nr San Andreas Lndg	WIMS	92	2.8	133	20	6	24	15
28 a	San Joaquin River at Jersey Point	MWQI	54	13	746	304	12	30	20
28 d	San Joaquin River at Jersey Point	WIMS	11	11	178	46	10	19	15
29	San Joaquin River at Blind Point	WIMS	7	15	637	162	11	30	16
30 d	San Joaquin River at Antioch	WIMS	53	12	1620	247	9	56	20
32	Middle River at Tracy Road Bridge	WIMS	7	31	144	92	14	39	26
33 a	Middle River at Victoria Canal	MWQI	93	12	139	57	10	30	18
33 d	Middle River at Victoria Canal	WIMS	17	15	110	47	10	30	19
34	Middle River at Mokelumne Aqueduct	WIMS	103	12	92	36	8	30	16
35 a	Middle River at Bacon Island	MWQI	80	11	133	64	10	28	19
35 d	Middle River at Bacon Island	WIMS	10	26	135	74	15	21	18
36 d	Old River at Tracy Road Bridge	WIMS	105	14	228	96	9	81	34
37	Old River near Tracy	WIMS	41	17	258	126	1	67	38
38	Grant Line Canal at Tracy Road Bridge	WIMS	35	12	232	146	10	62	41
39	Old River upstream of temporary barrier	MWQI	50	38	177	109	14	54	26
40	Delta-Mendota Canal Intake	MWQI	113	16	179	87	9	52	24
41	Delta-Mendota Canal at Byron Road	WIMS	163	17	256	90	8	62	27
42	Delta-Mendota Canal near Tracy	WIMS	67	18	224	81	6	65	25
43	Grant Line Canal near Old River	MWQI	48	36	180	111	14	63	29
44 a	Old River near Clifton Court Intake	MWQI	46	37	181	106	14	47	23
44 d	Old River at Clifton Court Ferry	WIMS	40	14	188	71	10	52	23
45 a	Clifton Court Forebay Intake	MWQI	51	13	185	89	11	38	20
45 a	West Canal at Clifton Court Forebay	MWQI	56	5	177	100	11	42	20

Table 5.2 (continued)

Site	Description	Source	# samples	Chloride (mg/L) Min	Chloride (mg/L) Max	Chloride (mg/L) Avg	Calcium (mg/L) Min	Calcium (mg/L) Max	Calcium (mg/L) Avg
45 b	Clifton Court Forebay Entrance	O&M	158	11	176	57	8	39	18
46 a	Banks Pumping Plant	MWQI	116	15	185	86	9	30	19
46 b	Banks Pumping Plant	O&M	374	12	305	66	2	45	18
47	North Canal near Old River	MWQI	51	3	155	78	13	26	19
48	Italian Slough	WIMS	64	15	328	82	8	49	22
49	Italian Slough	WIMS	23	16	175	71	10	51	25
50 a	Old River at Highway 4	MWQI	85	6	211	90	10	28	17
50 d	Old River at Highway 4	WIMS	26	22	293	100	11	49	23
51	North Victoria Canal near Old River	MWQI	50	3	213	98	13	25	18
52	Indian Slough near Brentwood	WIMS	41	22	390	99	11	102	33
53 a	Old River at SantaFe Railroad	MWQI	51	27	220	103	13	24	18
53 d	Old River at SantaFe Railroad	WIMS	40	14	164	59	9	53	20
54 a	Old River upstream of Rock Slough	MWQI	26	8	192	43	9	22	14
54 d	Old River near Rock Slough	WIMS	136	10	244	49	8	39	15
55	Rock Slough near Old River	MWQI	68	12	257	126	10	29	17
56	Rock Slough at CCC intake	WIMS	40	13	193	63	9	53	21
57	Contra Costa Canal Pumping Plant #1	MWQI	69	11	233	97	8	39	18
58 a	Old River downstream of Rock Slough	MWQI	57	10	257	133	10	23	17
58 d	Old River downstream of Rock Slough	WIMS	18	29	451	158	15	28	20
59	Old River at Holland Tract	WIMS	5	19	134	59	9	26	17
60	Sandmound Slough at Old River	MWQI	57	10	245	132	10	23	17
61	Old River at Mandeville Island	WIMS	39	10	181	44	10	38	18
62	Franks Tract at Russo Landing	WIMS	8	13	206	52	11	19	15
63	False River at Webb Pump	WIMS	4	12	59	36	7	18	14
65	False River at southmost tip of Webb Tract	MWQI	48	12	540	200	12	26	18
66	Piper Slough at Bethel Tract	WIMS	79	11	420	75	7	25	14
67	False River below Piper Slough	WIMS	9	46	543	215	15	30	20
68	Dutch Slough at Bethel Island Bridge	WIMS	6	30	273	89	10	23	18
69	Dutch Slough at Jersey Island Bridge	WIMS	9	38	712	275	14	36	24
71 d	Mokelumne River near Thorton	WIMS	10	0.2	7	3	3	13	7
72	Hog Slough	WIMS	13	24	212	89	14	60	32
74 d	Little Potato Slough at Terminous	WIMS	47	8	42	19	5.2	20	14
75	Mokelumne River at Highway 12	WIMS	8	9	15	11	10	16	14
76	Disappointment Slough near Lodi	WIMS	13	5	69	23	11	33	19
78	Calaveras River at Stockton	WIMS	29	3	46	8	8.3	40	20
79	North Bay Aqueduct	O&M	45	8	67	28	8	28	18
80	Lindsay Slough at Hastings Cut	WIMS	46	6	79	38	4	26	19
81	Lindsey Slough near Rio Vista	WIMS	75	6	35	15	3	25	15

Preliminary



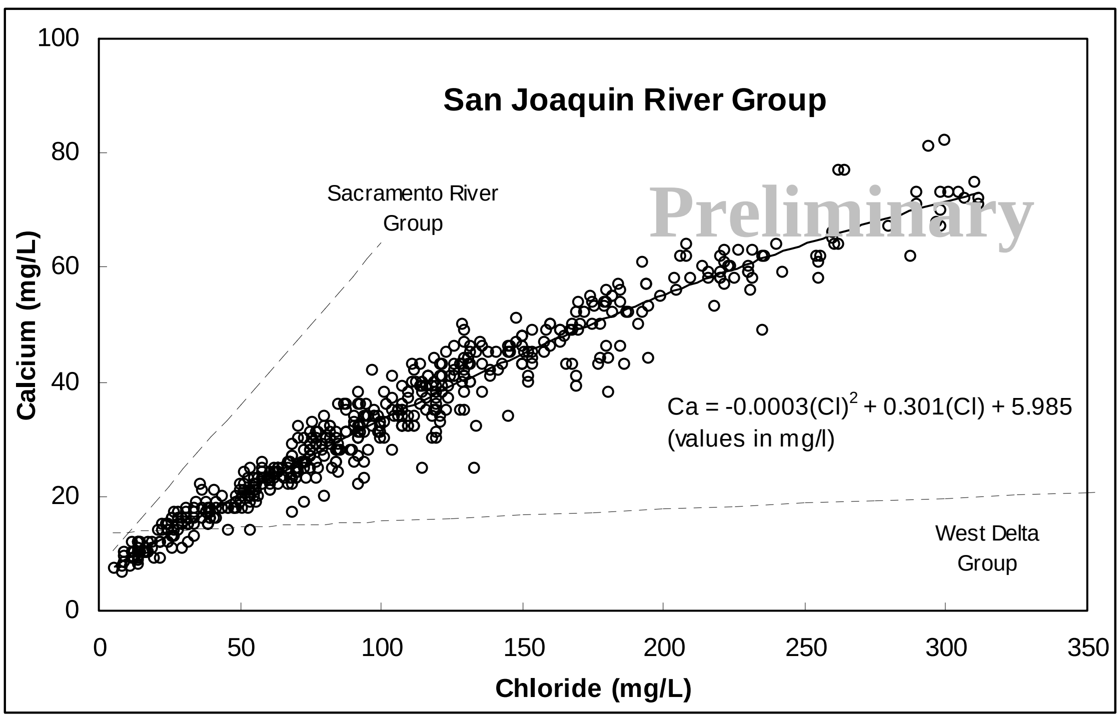


Figure 5.2: Relationship Between Chloride and Calcium for West Delta and San Joaquin River Regions.

Table 5.3: Preliminary Regressions for Calcium and Chloride Analysis.

Location	Total # Samples	Cl (mg/L) Min	Cl (mg/L) Max	Ca (mg/L) Min	Ca (mg/L) Max	X^2 Coeff	X Coeff	Intercept	R^2	SE (mg/L)
Sacramento River Group Sacramento to Rio Vista (1,2,3,4d,5a,5d,6,7d,8)	511	1	23	4	88	none	0.565	7.71	0.48	1.86
West Delta Group Jersey Point to Chipps Island (12a,12c,28a,28c,28d,29,30c,30d)	268	7	6060	8	138	none	0.0207	13.53	0.99	3.77
San Joaquin River Group Vernalis to Rindge Tract (19c,19d,20c,20d,21,22,24)	531	6	505	7	105	-0.00027	0.301	5.99	0.95	3.43

As Figure 5.3 shows, the relationship between chloride and calcium in these regions follows that of the San Joaquin River group up to 50 to 100 mg/l chloride, and then follows the west Delta regression at higher chloride concentrations. It is likely that during low chloride concentrations, when the Delta outflow is high, the main source of water in the Contra Costa Canal and Franks Tract regions are the Sacramento and San Joaquin rivers. Relationships between constituents during high Delta outflow simply reflect the source of water. As the concentration of chloride increases, Delta outflow decreases and the source of water increasingly is the west Delta.

Figure 5.4 shows the relationships at the DMC and SWP intakes. The complex relationship between chloride and calcium in the DMC group implies substantial mixing of water; however, the data is roughly bounded between the San Joaquin River group and the west Delta group regressions. The relationship between the two constituents in the SWP intake group at times follows the west Delta group and at other times is consistent with the San Joaquin River group. The trends for these two groups demonstrate that further work is needed to explain the mixing of water at the DMC and SWP intakes.

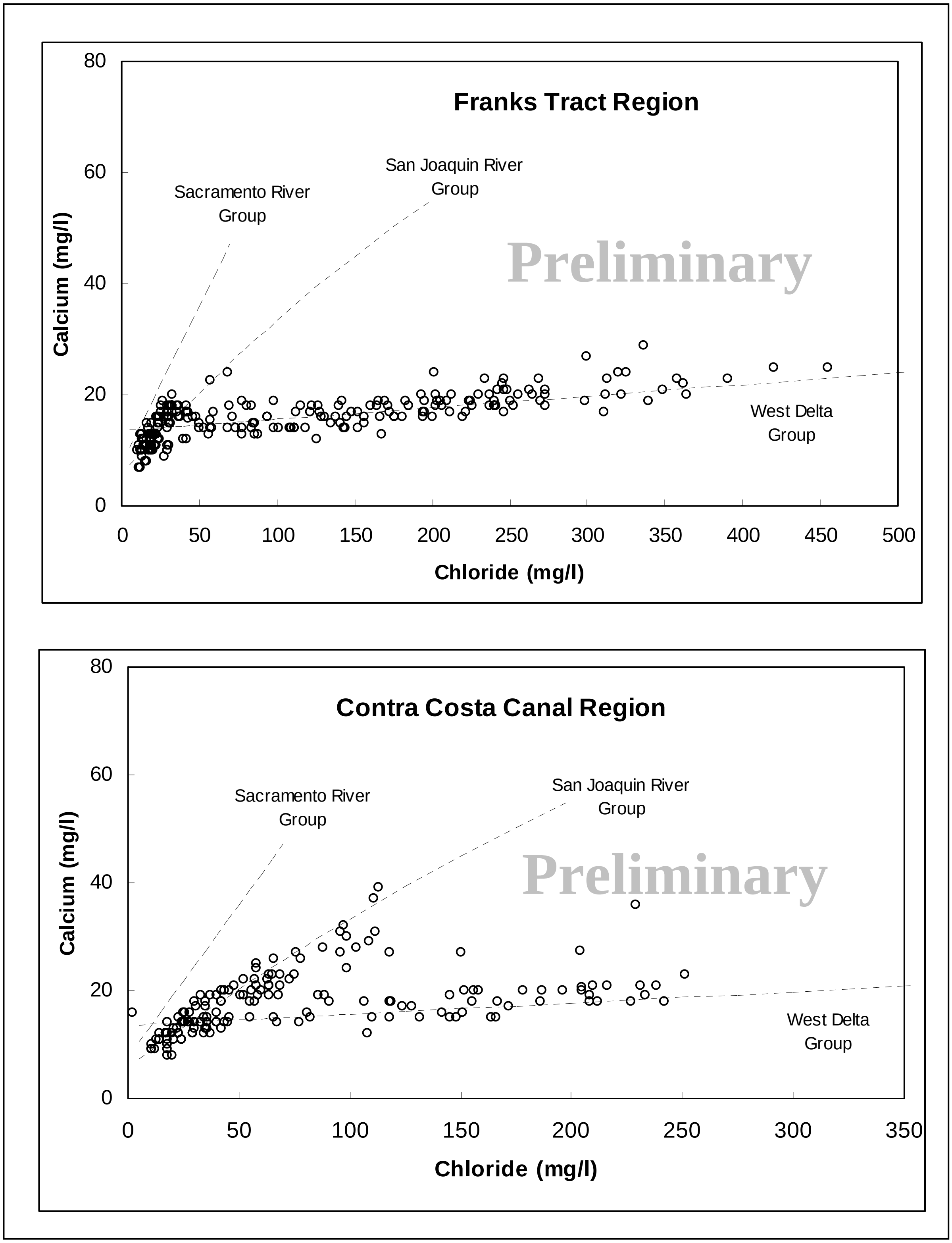


Figure 5.3: Relationship Between Chloride and Calcium for Franks Tract and Contra Costa Canal Regions.

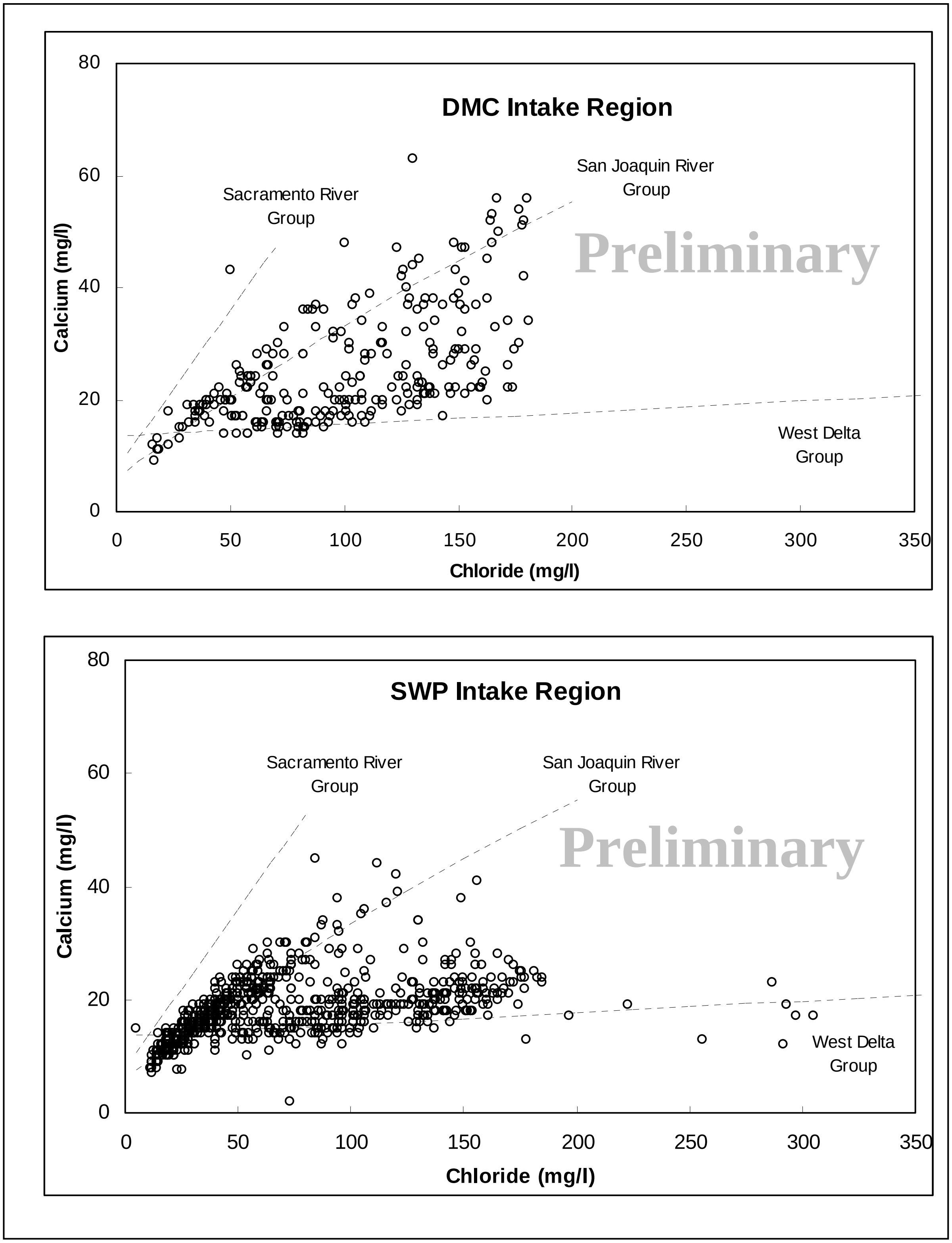


Figure 5.4: Relationship Between Chloride and Calcium for DMC and SWP Intake Regions.

5.5 Future Directions

At the time of this writing, much of the analysis has been done and is being summarized. For regions on the periphery of the Delta where water mixing is less complex, this analysis will be directly applicable to QUAL validation. At interior Delta locations, complex mixing of west Delta, Sacrament River, and San Joaquin River sources occurs and the current analysis does not explain or predict this. What is possible to predict for such regions is bounding the expected relationship between any two constituents as modeled by QUAL. Future analysis with grab sample data and concurrent Delta flow patterns may give insight on predicting how relationships between two constituents may change based upon hydrologic conditions. Sufficient data should already exist to both develop and test some simple predictive models.

5.6 Reference

Guivetchi, K. (1986). *Salinity Unit Conversion Equations*. Memorandum. California Department of Water Resources. Sacramento, CA.