C-6 STATISTICAL WATER QUALITY IMPACT ANALYSIS

Table of Contents

Tables

Introduction

Changes in timing and location of diversions have the potential to affect water quality conditions in the Delta. The water quality impacts and benefits analysis focuses on salinity (reported as electrical conductivity and chloride concentration) as an indicator of Delta water quality because salinity is the Delta water quality constituent most likely to be affected by shifts in the timing and location of pumping in the Delta. Salinity is also the constituent for which the most monitoring data and calibrated Delta modeling tools exist.

To assess the potential water quality impacts and benefits of the project alternatives, the results of CalSim II studies were input into the DSM2 water quality model for the Delta, and estimated Delta salinity concentrations were compared between each project alternative study and the relevant without project conditions under the existing or future level of development. Water quality analysis for these project alternatives was performed for the 16-year period from 1975 – 1991.

It is important to note that not all of the differences in simulated salinity are necessarily due to changes in operations under the project alternatives. Model artifacts as discussed in Section 4.2.2 and project operations both contribute to potential water quality impacts. In order to determine if the changes in water quality posed potentially significant impacts, several statistical tests were used (Zar, 1999).

D1641 Water Quality Standards

Compliance with the D1641 water quality standards was assessed at the standard compliance locations in each of the model runs (without project and four alternatives). The compliance locations included Emmaton, Jersey Point, Brandt Bridge, Old River near Middle River, Old River near Tracy Bridge, and Old River at Rock Slough. The standards for each station are listed below in **Table C6-1.**

TABLE C6-1:
SUMMARY OF WATER QUALITY STANDARDS FOR SELECT LOCATIONS IN THE DELTA

Compliance Location	Description	Value
Sac River @ Emmaton	14 day running average of mean EC during the spring and summer months depending on water year type	0.45-2.78 (mmhos/cm) depending on water year type and time of year
San Joaquin River @ Jersey Pt	14 day running average of mean EC during the spring and summer months depending on water year type	.45 -2.20 (mmhos/cm) depending on water year type and time of year
San Joaquin River @ Brandt Bridge	Maximum 30 day running average of mean daily EC	Apr – Aug 0.7 (mmhos/cm) Sep – Mar 1.0 (mmhos/cm)
Old River near Middle River	Maximum 30 day running average of mean daily EC	Apr – Aug 0.7 (mmhos/cm) Sep – Mar 1.0 (mmhos/cm)
Old River @ Tracy Bridge	Maximum 30 day running average of mean daily EC	Apr – Aug 0.7 (mmhos/cm) Sep – Mar 1.0 (mmhos/cm)
Old River @ Rock Slough	Maximum mean daily Cl	250 Cl

Potential standards violations were found in all model runs, including the existing and future without project runs. In reality, water system operators manage the system so that water quality standard violations are avoided. However, a recognized issue in using CalSim II inputs to DSM2 is that the estimation of Delta water quality is approached differently by the two models. This sometimes leads to a condition in which the CalSim II model estimates the amount of outflow required to avoid causing a Delta water quality violation, but the subsequent DSM2 estimate of Delta salinity shows that the standard was exceeded. This model mismatch is responsible for water quality standard violations in the existing condition model run but also contributes to the number of violations under the project alternatives.

If the project alternative operations caused a significant impact to water quality standards, the frequency of standards violations in the without project case and alternatives would be significantly different. Specifically, if project operations caused a water quality impact, the frequency of violations for that project would be significantly greater than the frequency of violations for the without project operation. The occurrence of standards violations under the without project conditions were compared to the occurrence under the various alternative conditions. A contingency table (χ^2) was used to determine if the occurrence of standards violations under the project alternatives were significantly different (more or less frequent) than the occurrence under the without project condition. The χ^2 was calculated using the Yates correction for continuity. The following example demonstrates the calculation used (**Table C6-2**).

TABLE C6-2:
EXAMPLE OF 2-BY-2 CONTINGENCY TABLE

	Days With Violation	Days Without Violation	Total
Without Project	a	b	a+b
Alternative	c	d	c+d
Total	a+c	b+d	a+b+c+d = N

$$\chi^2 = \frac{N(ad - bc - \frac{N}{2})^2}{(a+b)(c+d)(b+d)(a+c)}$$

The p-values were calculated using the EXCEL function CHIDIST for one degree of freedom. At the 95% confidence interval, a significant result is a calculated p-value less than 0.05. If there was a significant difference between the without project violations and alternatives, it was assumed that the changes in operations cause a significant impact to water quality. **Table C6-3** through **Table C6-6** present the contingency tables and the results for each alternative.

The only instance of a statistically significant difference between the without project runs and alternative runs was at Rock Slough. The frequency of violations was significantly less than the without project runs for Alternatives 1, 2 and 3 assuming the moderate fisheries restrictions and future level of development. Additionally there were significantly fewer violations for Alternative 3 assuming severe fishery restrictions and future level of development. In all other locations and scenarios there were no significant differences between the frequency of water standards

violations in the without project and alternatives conditions. Therefore, we conclude that there were no significant impacts.

Protection of Beneficial Uses

In addition to assessing project compliance with enforceable water quality standards, water quality changes were analyzed elsewhere in the Delta to ensure that the project alternatives did not affect beneficial uses. Unlike the standards violation analysis described above, the analysis of potential impacts to beneficial uses involved a direct comparison of water quality in the without project conditions and water quality with each of the project alternatives. Small differences, described in more detail below, were eliminated from further consideration and water quality changes that could be large enough to cause a change in beneficial use were further investigated. Changes in water quality were analyzed at existing and planned Delta drinking water intakes: Jones Pumping Plant, Clifton Court Forebay, Barker Slough, Cache Slough, San Joaquin River at Antioch and San Joaquin River at Empire Tract.

A sizeable increase in salinity was defined as a salinity difference between a project alternative and the without project condition greater than 5% and greater than 5 mg/l Cl. A sizeable decrease in salinity was defined as a salinity difference between a project alternative and the without project condition that is less than -5% and greater than -5 mg/l Cl.

Sizeable changes at the City of Antioch intake were defined separately because an operational threshold is established at that location, and effects on the beneficial use could be caused by changing the amount of time that Antioch's source water salinity is below that threshold. When chloride concentration is greater than 250 mg/L, the City of Antioch uses water from other sources. If the existing or future without project monthly average chloride concentration was modeled as less than 250 mg/L and operations under a project alternative increased the concentration to 250 mg/L Cl or more, the month was flagged as a sizeable increase in salinity. Conversely, if chloride concentration was modeled as greater than 250 mg/L in the existing or future without project run and was lowered below 250 mg/L Cl under a project alternative, the month was a sizeable salinity decrease.

If there was no statistically significant difference in the number of increases compared to decreases, then the changes found in the alternatives runs were attributed to threshold sensitivity and it was assumed that there would be no significant impact to beneficial uses. If there was a statistically significant difference, then it was assumed that project operations have to potential impact beneficial uses and was investigated further.

A one-tailed binomial test was used to determine if the likelihood of water quality degradation was significantly greater than the likelihood of a water quality improvement for a given alternative. The p-values were calculated using the EXCEL function BINOMDIST which required the following input: the number of improvements, total number of improvements plus degradations, an expected probability of 0.5, and a flag to indicate the functional form ("false" returns the probability mass function). At the 95% confidence interval, a significant result is a

calculated p-value less than 0.05. **Table C6-7** through **Table C6-10** present the data used and the results.

The only time a significant difference was found was for Alternative 3 at Barker Slough assuming moderate fisheries restrictions and existing levels of development. The number of degradations was 10 compared to zero improvements. Further investigation indicated that the number of sizeable salinity increases was influenced by an event lasting several consecutive months where changes not related to Alternative 3 caused the changes in salinity. It was concluded that this estimated difference in Barker Slough water quality does not reflect an impact that would be caused by the Alternative 3 operations. Based on this analysis we conclude that for Alternatives 1, 2, 3 and 4 there are no significant impacts due to changes in project operations.

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TABLE C6-3: CHI-SQUARED AND P-VALUES FOR WATER QUALITY STANDARDS VIOLATIONS IN ALTERNATIVE 1 AND WITHOUT PROJECT CONDITIONS

	Emmaton				Jersey Point				Brandt Bridge				Old River near Middle River				Old River near Tracy Bridge				Old River at Rock Slough			
	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value
2030 Level of Development; Moderate Fishery Restrictions																								
Future Without Project	247	5597			327	5517			554	5290			472	5372			503	5341			442	5402		
Alternative 1	243	5601	0.019	0.890	340	5504	0.229	0.632	555	5289	0.000	1.000	473	5371	0.000	1.000	507	5337	0.010	0.921	335	5509	15.491	8.29E-05
2005 Level of Development; Moderate Fishery Restrictions																								
Existing Condition	184	5660			169	5675			971	4873			956	4888			882	4962			218	5626		
Alternative 1	206	5638	1.170	0.279	164	5680	0.049	0.824	969	4875	0.001	0.980	956	4888	0.000	1.000	879	4965	0.003	0.959	211	5633	0.087	0.768
2005 Level of Development; Severe Fishery Restrictions																								
Existing Condition	171	5673			223	5621			973	4871			956	4888			943	4901			212	5632		
Alternative 1	171	5673	0.000	1.000	225	5619	0.962	0.327	974	4870	0.000	1.000	956	4888	0.000	1.000	944	4900	0.000	1.000	224	5620	0.288	0.591
2030 Level of Development; Severe Fishery Restrictions																								
Future Without Project	220	5624			359	5485			540	5304			474	5370			544	5300			451	5393		
Alternative 1	232	5612	0.278	0.598	380	5464	0.578	0.447	539	5305	0.000	1.000	475	5369	0.000	1.000	549	5295	0.016	0.899	421	5423	1.042	0.307

TABLE C6-4: CHI-SQUARED AND P-VALUES FOR WATER QUALITY STANDARDS VIOLATIONS IN ALTERNATIVE 2 AND WITHOUT PROJECT CONDITIONS

	Emmaton				Jersey Point				Brandt Bridge				Old River near Middle River				Old River near Tracy Bridge				Old River at Rock Slough			
	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value
2030 Level of Development; Moderate Fishery Restrictions																								
Future Without Project	247	5597			327	5517			554	5290			472	5372			503	5341			442	5402		
Alternative 2	246	5598	0.000	1.000	350	5494	0.759	0.384	556	5288	0.001	0.975	472	5372	0.000	1.000	505	5339	0.001	0.974	357	5487	9.479	0.002
2005 Level of Development; Moderate Fishery Restrictions																								
Existing Condition	184	5660			169	5675			971	4873			956	4888			882	4962			218	5626		
Alternative 2	170	5674	0.000	1.000	162	5682	0.112	0.738	970	4874	0.000	1.000	956	4888	0.000	1.000	881	4963	0.000	1.000	205	5639	0.353	0.552
2005 Level of Development; Severe Fishery Restrictions																								
Existing Condition	171	5673			223	5621			973	4871			956	4888			943	4901			212	5632		
Alternative 2	239	5605	0.000	1.000	224	5620	0.000	1.000	974	4870	0.000	1.000	956	4888	0.000	1.000	944	4900	0.000	1.000	227	5617	0.464	0.496
2030 Level of Development; Severe Fishery Restrictions																								
Future Without Project	220	5624			359	5485			540	5304			474	5370			544	5300			451	5393		
Alternative 2	239	5605	0.735	0.391	376	5468	0.372	0.542	539	5305	0.000	1.000	474	5370	0.000	1.000	546	5298	0.001	0.975	425	5419	0.771	0.380

TABLE C6-5: CHI-SQUARED AND P-VALUES FOR WATER QUALITY STANDARDS VIOLATIONS IN ALTERNATIVE 3 AND WITHOUT PROJECT CONDITIONS

	Emmaton				Jersey Point				Brandt Bridge				Old River near Middle River				Old River near Tracy Bridge				Old River at Rock Slough			
	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value
2030 Level of Development; Moderate Fishery Restrictions																								
Future Without Project	247	5597			327	5517			554	5290			472	5372			503	5341			442	5402		
Alternative 3	235	5609	0.262	0.609	320	5524	0.059	0.808	549	5295	0.016	0.899	472	5372	0.000	1.000	503	5341	0.000	1.000	335	5509	15.491	8.29E-05
2005 Level of Development; Moderate Fishery Restrictions																								
Existing Condition	184	5660			169	5675			971	4873			956	4888			882	4962			218	5626		
Alternative 3	204	5640	0.962	0.327	177	5667	0.146	0.702	970	4874	0.000	1.000	956	4888	0.000	1.000	879	4965	0.003	0.959	225	5619	0.084	0.771
2005 Level of Development; Severe Fishery Restrictions																								
Existing Condition	171	5673			223	5621			973	4871			956	4888			943	4901			212	5632		
Alternative 3	173	5671	0.003	0.956	225	5619	0.002	0.962	973	4871	0.000	1.000	956	4888	0.000	1.000	942	4902	0.000	1.000	234	5610	1.028	0.311
2030 Level of Development; Severe Fishery Restrictions																								
Future Without Project	220	5624			359	5485			540	5304			474	5370			544	5300			451	5393		
Alternative 3	217	5627	0.010	0.922	355	5489	0.013	0.908	543	5301	0.004	0.949	475	5369	0.000	1.000	541	5303	0.004	0.949	374	5470	7.533	0.006

TABLE C6-6: CHI-SQUARED AND P-VALUES FOR WATER QUALITY STANDARDS VIOLATIONS IN ALTERNATIVE 4 AND WITHOUT PROJECT CONDITIONS

	Emmaton				Jersey Point				Brandt Bridge				Old River near Middle River				Old River near Tracy Bridge				Old River at Rock Slough			
	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value	# of days **with** Water Quality Violation	# of days **without** Water Quality Violation	X^2	p-value
2030 Level of Development; Moderate Fishery Restrictions																								
Future Without Project	247	5597			327	5517			554	5290			472	5372			503	5341			442	5402		
Alternative 4	248	5596	0.000	1.000	330	5514	0.006	0.936	554	5290	0.000	1.000	472	5372	0.000	1.000	504	5340	0.000	1.000	423	5421	0.405	0.525
2005 Level of Development; Moderate Fishery Restrictions																								
Existing Condition	184	5660			169	5675			971	4873			956	4888			882	4962			218	5626		
Alternative 4	188	5656	0.025	0.874	169	5675	0.000	1.000	971	4873	0.000	1.000	956	4888	0.000	1.000	881	4963	0.000	1.000	199	5645	0.806	0.369
2005 Level of Development; Severe Fishery Restrictions																								
Existing Condition	171	5673			223	5621			973	4871			956	4888			943	4901			212	5632		
Alternative 4	172	5672	0.000	1.000	225	5619	0.002	0.962	973	4871	0.000	1.000	956	4888	0.000	1.000	943	4901	0.000	1.000	227	5617	0.464	0.496
2030 Level of Development; Severe Fishery Restrictions																								
Future Without Project	220	5624			359	5485			540	5304			474	5370			544	5300			451	5393		
Alternative 4	221	5623	0.000	1.000	356	5488	0.006	0.938	540	5304	0.000	1.000	474	5370	0.000	1.000	543	5301	0.000	1.000	418	5426	1.273	0.259

TABLE C6-7: BINOMIAL DISTRIBUTION TEST FOR POTENTIAL IMPACTS TO BENEFICIAL USES IN ALTERNATIVE 1

	Jones Pumping (CVP)				West Canal at Clifton Ct Forebay (SWP)				Barker Slough (NBA)				Cache Slough (City of Vallejo)				San Joaquin River at Empire Tract (City of Stockton DWSP)				San Joaquin River at Antioch (City of Antioch)			
	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value
2030 Level of Development; Moderate Fishery Restrictions	4	4	8	0.64	6	5	11	0.50	2	0	2	0.25	0	0	0	1.00	4	11	15	0.98	1	0	1	0.5
2005 Level of Development; Moderate Fishery Restrictions	3	3	6	0.66	4	2	6	0.34	0	2	2	1.00	0	1	1	1.00	2	1	3	0.50	0	0	0	1
2030 Level of Development; Severe Fishery Restrictions	5	3	8	0.36	7	5	12	0.39	0	0	0	1.00	0	0	0	1.00	4	5	9	0.75	0	0	0	1
2005 Level of Development; Severe Fishery Restrictions	2	0	2	0.25	3	0	3	0.13	0	0	0	1.00	0	0	0	1.00	1	0	1	0.50	1	1	2	0.75

TABLE C6-8: BINOMIAL DISTRIBUTION TEST FOR POTENTIAL IMPACTS TO BENEFICIAL USES IN ALTERNATIVE 2

	Jones Pumping (CVP)				West Canal at Clifton Ct Forebay (SWP)				Barker Slough (NBA)				Cache Slough (City of Vallejo)				San Joaquin River at Empire Tract (City of Stockton DWSP)				San Joaquin River at Antioch (City of Antioch)			
	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value
2030 Level of Development; Moderate Fishery Restrictions	6	3	9	0.25	8	3	11	0.11	2	0	2	0.25	0	0	0	1.00	5	7	12	0.81	1	0	1	0.5
2005 Level of Development; Moderate Fishery Restrictions	3	1	4	0.31	4	0	4	0.06	0	3	3	1.00	0	0	0	1.00	2	0	2	0.25	0	0	0	1
2030 Level of Development; Severe Fishery Restrictions	4	3	7	0.50	9	4	13	0.13	0	0	0	1.00	0	0	0	1.00	5	4	9	0.50	0	0	0	1
2005 Level of Development; Severe Fishery Restrictions	2	0	2	0.25	4	0	4	0.06	0	0	0	1.00	0	0	0	1.00	1	0	1	0.50	0	1	1	1

TABLE C6-9: BINOMIAL DISTRIBUTION TEST FOR POTENTIAL IMPACTS TO BENEFICIAL USES IN ALTERNATIVE 3

	Jones Pumping (CVP)				West Canal at Clifton Ct Forebay (SWP)				Barker Slough (NBA)				Cache Slough (City of Vallejo)				San Joaquin River at Empire Tract (City of Stockton DWSP)				San Joaquin River at Antioch (City of Antioch)			
	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value
2030 Level of Development; Moderate Fishery Restrictions	5	10	15	0.94	5	11	16	0.96	2	0	2	0.25	0	0	0	1.00	5	13	18	0.98	0	0	0	1
2005 Level of Development; Moderate Fishery Restrictions	3	2	5	0.50	4	2	6	0.34	10	0	10	0.001	0	1	1	1.00	8	2	10	0.05	1	0	1	0.5
2030 Level of Development; Severe Fishery Restrictions	7	6	13	0.50	7	7	14	0.60	1	0	1	0.50	0	0	0	1.00	9	7	16	0.40	1	0	1	0.5
2005 Level of Development; Severe Fishery Restrictions	1	0	1	0.50	1	0	1	0.50	0	0	0	1.00	0	0	0	1.00	1	0	1	0.50	1	0	1	0.5

TABLE C6-10: BINOMIAL DISTRIBUTION TEST FOR POTENTIAL IMPACTS TO BENEFICIAL USES IN ALTERNATIVE 4

	Jones Pumping (CVP)				West Canal at Clifton Ct Forebay (SWP)				Barker Slough (NBA)				Cache Slough (City of Vallejo)				San Joaquin River at Empire Tract (City of Stockton DWSP)				San Joaquin River at Antioch (City of Antioch)			
	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value	Sizeable Salinity Increase	Sizeable Salinity Decrease	Sum	p-value
2030 Level of Development; Moderate Fishery Restrictions	0	1	1	1.00	0	1	1	1.00	0	0	0	1.00	0	0	0	1.00	0	2	2	1.00	0	0	0	1
2005 Level of Development; Moderate Fishery Restrictions	0	0	0	1.00	0	0	0	1.00	0	1	1	1.00	0	0	0	1.00	0	1	1	1.00	1	0	1	0.5
2030 Level of Development; Severe Fishery Restrictions	1	4	5	0.97	1	5	6	0.98	0	0	0	1.00	0	0	0	1.00	1	3	4	0.94	0	0	0	1
2005 Level of Development; Severe Fishery Restrictions	0	0	0	1.00	0	0	0	1.00	0	0	0	1.00	0	0	0	1.00	0	0	0	1.00	0	0	0	1