Appendix 6.A. Quantitative Methods for Biological Assessment of Delta Smelt

6.A Quantitative Methods for Biological Assessment of Delta Smelt

6.A.1 Introduction

This appendix describes the methods for the main quantitative analyses undertaken for Delta Smelt in Chapter 6, *Effects Analysis for Delta Smelt and Terrestrial Species*. The appendix is divided into methods related to North Delta Exports, South Delta Exports, and Habitat Effects. In general, only the methods are reported in this appendix; the results are described in Chapter 6. Exceptions include more detailed results for certain analyses.

6.A.2 North Delta Exports

6.A.2.1 Migrating Adult Movement Upstream (DSM2-PTM)

Of concern related to the construction and operation of the NDD is the potential for Delta Smelt to occur close to the NDD. In addition to survey data, a DSM2-PTM analysis was undertaken to assess the potential for upstream migration of adult Delta Smelt to the vicinity of the NDD. The analysis essentially sought to reproduce the methods of Sommer et al. (2011), who applied a tidally varying vertical migration behavior to assess potential upstream migration rate of Delta Smelt in order to validate empirical estimates of migration rate from salvage data.

6.A.2.1.1 Methods

The methods for the DSM2-PTM analysis of migrating adult Delta Smelt upstream migration are provided in Appendix 5.B, Section 5.B.3.6, *Corroboration of Scenario with 15 cm Sea Level Rise*.

6.A.2.1.2 Results

The principal results of the upstream migration analysis are presented in Chapter 6, Section 6.1.3.2.2.1.2, *Population-Level Effects*. This section provides additional results for the geographic subregions that particles were found in at the end of the 30-day simulation period (Table 6.A-1, Table 6.A-2, Table 6.A-3, and Table 6.A-4).

Table 6.A-1. Adult Delta Smelt Upstream Movement Analysis Based on DSM2-PTM: Fate (Mean Percentage) of Particles by Release Location, Water Year Type, and Geographic Subregion (West Suisun Bay to San Joaquin River at Twitchell Island) After 30 Days

Release Location	Water Year Type	West Suisun Bay			Mid Suisun Bay			Suisun Marsh			Honker Bay			Lower San Joaquin River			San Joaquin River at Twitchell Island		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Cache Sl. at Liberty Island (Node 323)	W	0.6	0.6	0.0 (-4%)	3.2	2.9	-0.3 (-10%)	3.1	2.8	-0.3 (-9%)	1.5	1.7	0.3 (18%)	2.2	2.5	0.3 (15%)	1.0	1.0	0.0 (2%)
	AN	1.0	1.2	0.2 (23%)	3.1	3.9	0.7 (24%)	2.8	3.1	0.3 (12%)	1.1	1.3	0.2 (18%)	1.9	2.0	0.1 (3%)	0.8	0.9	0.0 (5%)
	BN	0.2	0.2	0.0 (-22%)	3.9	3.5	-0.4 (-10%)	2.8	2.6	-0.3 (-10%)	1.6	1.9	0.3 (21%)	2.8	3.6	0.9 (31%)	1.0	1.5	0.5 (45%)
	D	0.3	0.3	0.0 (-1%)	1.7	1.7	0.0 (2%)	1.4	1.3	-0.1 (-5%)	1.2	0.9	-0.2 (-21%)	2.0	1.9	-0.1 (-4%)	1.0	1.0	0.0 (1%)
	C	0.0	0.0	0.0 (-50%)	0.8	0.7	-0.1 (-7%)	0.9	0.7	-0.2 (-21%)	0.7	0.4	-0.3 (-37%)	1.2	1.1	-0.1 (-8%)	0.5	0.6	0.1 (16%)
Decker Island (Node 353)	W	0.5	0.5	0.0 (-7%)	4.4	4.5	0.2 (4%)	6.4	6.3	-0.1 (-1%)	1.0	1.5	0.4 (43%)	1.9	2.5	0.6 (34%)	0.8	1.1	0.3 (41%)
	AN	0.4	0.5	0.1 (26%)	2.0	1.9	-0.1 (-3%)	4.7	4.3	-0.3 (-7%)	0.9	0.7	-0.1 (-16%)	3.1	3.3	0.1 (4%)	1.2	1.0	-0.1 (-10%)
	BN	0.1	0.2	0.1 (89%)	4.9	7.1	2.2 (44%)	5.9	7.7	1.8 (30%)	2.7	3.5	0.8 (29%)	5.2	6.5	1.3 (25%)	2.8	3.5	0.7 (26%)
	D	0.4	0.4	0.0 (5%)	4.9	4.0	-0.9 (-18%)	5.7	4.7	-1.0 (-17%)	3.4	3.2	-0.2 (-6%)	7.0	7.2	0.2 (3%)	4.5	5.3	0.7 (16%)
	C	0.1	0.0	0.0 (-67%)	2.0	1.5	-0.4 (-22%)	3.2	2.9	-0.3 (-10%)	1.7	1.5	-0.2 (-13%)	6.7	6.5	-0.2 (-3%)	5.4	5.4	0.1 (1%)
Montezuma Slough (Node 420)	W	0.1	0.1	0.0 (1%)	0.2	0.2	0.0 (-6%)	80.8	81.1	0.4 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	0.0	0.0	0.0 (92%)	0.3	0.4	0.1 (54%)	99.1	99.0	-0.2 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	0.0	0.0	0.0 (-100%)	0.5	0.1	-0.5 (-88%)	99.2	99.9	0.7 (1%)	0.0	0.0	0.0 (-94%)	0.0	0.0	0.0 (-75%)	0.0	0.0	0.0 (0%)
	D	0.0	0.0	0.0 (-59%)	0.7	0.4	-0.3 (-39%)	98.8	99.3	0.5 (0%)	0.1	0.1	0.0 (-18%)	0.0	0.0	0.0 (-26%)	0.0	0.0	0.0 (0%)
	C	0.1	0.0	0.0 (-40%)	2.6	2.2	-0.4 (-16%)	95.6	96.6	1.0 (1%)	0.4	0.3	-0.1 (-28%)	0.2	0.1	-0.1 (-35%)	0.0	0.0	0.0 (-33%)
Chipps Island (Node 465)	W	0.4	0.4	0.0 (13%)	4.2	4.6	0.4 (10%)	6.1	6.7	0.5 (9%)	0.9	1.2	0.3 (34%)	1.1	1.8	0.7 (59%)	0.4	0.6	0.2 (48%)
	AN	0.3	0.4	0.1 (39%)	1.2	1.3	0.0 (4%)	6.6	6.5	-0.1 (-1%)	0.7	0.5	-0.2 (-28%)	2.2	2.4	0.2 (11%)	0.7	0.7	0.0 (-5%)
	BN	0.1	0.2	0.1 (138%)	5.8	8.0	2.2 (37%)	9.8	11.1	1.3 (13%)	2.9	3.2	0.4 (13%)	4.8	5.6	0.8 (16%)	2.7	3.3	0.6 (21%)
	D	0.5	0.4	-0.1 (-15%)	6.3	5.7	-0.6 (-9%)	11.4	10.4	-1.0 (-9%)	3.6	3.6	0.1 (2%)	6.6	7.5	0.9 (13%)	4.3	5.1	0.8 (17%)
	C	0.1	0.0	-0.1 (-57%)	2.6	2.3	-0.3 (-10%)	11.4	10.6	-0.7 (-6%)	2.0	1.9	-0.1 (-5%)	7.9	8.3	0.5 (6%)	6.0	6.3	0.2 (4%)

Note: Grey shading indicates that no particles had this fate for either the NAA or PA.

Table 6.A-2. Adult Delta Smelt Upstream Movement Analysis Based on DSM2-PTM: Fate (Mean Percentage) of Particles by Release Location, Water Year Type, and Geographic Subregion (Franks Tract to Old River) After 30 Days

Release Location	Water Year Type	Franks Tract			San Joaquin River at Prisoners Point			Holland Cut			Mildred Island			Rock Slough and Discovery Bay			Old River		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Cache Sl. at Liberty Island (Node 323)	W	0.4	0.5	0.1 (29%)	1.2	1.3	0.1 (11%)	0.6	0.6	0.1 (11%)	0.5	0.7	0.2 (32%)	0.1	0.1	0.0 (8%)	0.3	0.3	0.0 (4%)
	AN	0.4	0.5	0.1 (25%)	0.8	0.8	0.1 (8%)	0.4	0.5	0.1 (19%)	0.4	0.4	0.0 (-1%)	0.1	0.1	0.0 (-3%)	0.2	0.2	0.0 (13%)
	BN	0.4	0.6	0.2 (43%)	1.3	1.6	0.3 (24%)	0.6	0.8	0.2 (38%)	0.5	0.5	0.0 (9%)	0.1	0.1	0.0 (60%)	0.2	0.2	0.0 (16%)
	D	0.5	0.5	0.0 (8%)	1.4	1.5	0.1 (9%)	0.7	0.7	0.0 (1%)	0.7	0.6	-0.1 (-9%)	0.1	0.1	0.0 (-11%)	0.3	0.3	0.0 (-2%)
	C	0.2	0.2	0.0 (15%)	0.5	0.5	0.0 (5%)	0.2	0.2	0.0 (12%)	0.2	0.2	0.0 (-3%)	0.0	0.0	0.0 (0%)	0.1	0.1	0.0 (0%)
Decker Island (Node 353)	W	0.5	0.7	0.2 (36%)	1.3	1.8	0.5 (44%)	0.6	0.9	0.3 (45%)	0.6	0.7	0.1 (15%)	0.1	0.1	0.0 (30%)	0.3	0.3	0.1 (23%)
	AN	0.8	0.9	0.0 (3%)	2.0	2.0	0.0 (0%)	1.1	1.1	0.0 (-1%)	1.2	1.2	0.0 (-3%)	0.2	0.2	0.0 (19%)	0.5	0.5	0.0 (4%)
	BN	1.7	2.0	0.3 (15%)	5.1	5.9	0.8 (15%)	2.8	3.1	0.3 (12%)	3.3	3.3	0.0 (-1%)	0.5	0.5	0.0 (-5%)	1.2	1.2	-0.1 (-6%)
	D	2.8	3.2	0.4 (14%)	7.6	8.9	1.3 (17%)	3.7	4.4	0.7 (19%)	4.7	4.8	0.1 (2%)	0.7	0.8	0.1 (8%)	1.7	1.9	0.2 (9%)
	C	3.2	3.4	0.1 (4%)	10.2	10.4	0.2 (2%)	5.1	5.4	0.2 (5%)	6.8	7.1	0.3 (4%)	1.0	1.1	0.1 (12%)	2.2	2.5	0.3 (12%)
Montezuma Slough (Node 420)	W	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	D	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (-100%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	C	0.0	0.0	0.0 (-50%)	0.0	0.0	0.0 (-100%)	0.0	0.0	0.0 (-100%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
Chipps Island (Node 465)	W	0.2	0.3	0.1 (29%)	0.5	0.8	0.2 (44%)	0.2	0.3	0.1 (46%)	0.2	0.2	0.0 (9%)	0.0	0.0	0.0 (-24%)	0.1	0.1	0.0 (28%)
	AN	0.6	0.6	0.0 (-7%)	1.4	1.4	0.0 (-1%)	0.8	0.7	-0.1 (-7%)	0.9	0.8	-0.1 (-9%)	0.2	0.2	0.0 (8%)	0.3	0.3	0.0 (-12%)
	BN	1.6	1.8	0.2 (12%)	4.9	5.4	0.5 (10%)	2.3	2.5	0.2 (7%)	2.6	2.0	-0.6 (-22%)	0.3	0.3	0.0 (9%)	0.8	0.8	-0.1 (-7%)
	D	2.5	2.9	0.4 (17%)	6.8	7.9	1.1 (17%)	3.3	3.7	0.5 (14%)	3.4	3.2	-0.2 (-7%)	0.5	0.6	0.0 (5%)	1.2	1.4	0.2 (18%)
	C	3.6	3.6	0.0 (0%)	10.7	11.5	0.8 (8%)	5.2	5.5	0.3 (5%)	5.5	5.4	-0.1 (-2%)	0.8	0.8	0.0 (0%)	1.9	2.1	0.2 (9%)

Note: Grey shading indicates that no particles had this fate for either the NAA or PA.

Table 6.A-3. Adult Delta Smelt Upstream Movement Analysis Based on DSM2-PTM: Fate (Mean Percentage) of Particles by Release Location, Water Year Type, and Geographic Subregion (Middle River to San Joaquin River Near Stockton) After 30 Days

Release Location	Water Year Type	Middle River			Victoria Canal			Grant Line Canal and Old River			North and South Forks Mokelumne River			Disappointment Slough			San Joaquin River Near Stockton		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Cache Sl. at Liberty Island (Node 323)	W	0.2	0.2	0.0 (15%)	0.2	0.2	0.0 (-10%)	0.0	0.0	0.0 (83%)	0.1	0.1	0.0 (-3%)	0.0	0.0	0.0 (-43%)	0.2	0.1	-0.2 (-72%)
	AN	0.2	0.1	0.0 (-18%)	0.1	0.1	0.0 (-17%)	0.0	0.0	0.0 (0%)	0.1	0.1	0.0 (-12%)	0.0	0.0	0.0 (0%)	0.1	0.0	-0.1 (-68%)
	BN	0.2	0.2	0.0 (9%)	0.1	0.1	0.0 (16%)	0.0	0.0	0.0 (60%)	0.1	0.2	0.0 (24%)	0.0	0.0	0.0 (200%)	0.1	0.1	0.0 (-44%)
	D	0.2	0.2	0.0 (-1%)	0.2	0.2	0.0 (-3%)	0.0	0.0	0.0 (146%)	0.2	0.2	0.0 (-7%)	0.0	0.0	0.0 (13%)	0.4	0.2	-0.2 (-53%)
	C	0.1	0.1	0.0 (9%)	0.1	0.0	0.0 (-12%)	0.0	0.0	0.0 (700%)	0.1	0.1	0.0 (28%)	0.0	0.0	0.0 (-100%)	0.1	0.1	-0.1 (-44%)
Decker Island (Node 353)	W	0.3	0.2	0.0 (-13%)	0.2	0.2	0.0 (9%)	0.0	0.0	0.0 (65%)	0.2	0.2	0.0 (26%)	0.0	0.0	0.0 (225%)	0.2	0.1	-0.2 (-71%)
	AN	0.5	0.4	-0.1 (-14%)	0.4	0.3	-0.1 (-19%)	0.0	0.0	0.0 (-11%)	0.3	0.2	-0.1 (-19%)	0.0	0.0	0.0 (-67%)	0.4	0.3	-0.1 (-31%)
	BN	1.1	1.0	-0.1 (-11%)	0.8	0.8	0.0 (-3%)	0.1	0.1	0.1 (107%)	1.5	1.6	0.1 (4%)	0.2	0.1	-0.1 (-42%)	1.7	0.6	-1.2 (-66%)
	D	1.8	1.7	-0.1 (-7%)	1.4	1.5	0.1 (6%)	0.1	0.3	0.1 (98%)	1.2	1.4	0.2 (15%)	0.2	0.2	0.0 (6%)	2.5	1.3	-1.2 (-49%)
	C	2.7	2.8	0.1 (3%)	2.0	2.2	0.2 (12%)	0.3	0.6	0.3 (127%)	2.2	2.5	0.3 (16%)	0.5	0.6	0.0 (2%)	4.6	2.8	-1.7 (-38%)
Montezuma Slough (Node 420)	W	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	D	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	C	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
Chipps Island (Node 465)	W	0.1	0.1	0.0 (-26%)	0.0	0.0	0.0 (-21%)	0.0	0.0	0.0 (40%)	0.1	0.1	0.0 (41%)	0.0	0.0	0.0 (25%)	0.1	0.0	-0.1 (-85%)
	AN	0.4	0.3	-0.1 (-18%)	0.3	0.3	0.0 (0%)	0.0	0.0	0.0 (-48%)	0.2	0.2	0.0 (-15%)	0.0	0.0	0.0 (-33%)	0.4	0.3	-0.1 (-17%)
	BN	0.7	0.5	-0.2 (-30%)	0.5	0.4	0.0 (-7%)	0.0	0.1	0.0 (125%)	1.2	1.3	0.1 (7%)	0.1	0.1	0.0 (-47%)	0.9	0.3	-0.6 (-63%)
	D	1.1	0.9	-0.2 (-18%)	0.8	0.8	0.0 (-5%)	0.1	0.1	0.0 (47%)	1.0	1.3	0.2 (20%)	0.1	0.1	0.0 (-21%)	1.6	0.7	-0.9 (-55%)
	C	1.5	1.3	-0.2 (-16%)	1.2	1.2	-0.1 (-6%)	0.1	0.2	0.1 (123%)	2.3	2.6	0.3 (13%)	0.3	0.3	0.0 (-11%)	3.0	1.9	-1.2 (-38%)

Note: Grey shading indicates that no particles had this fate for either the NAA or PA.

Table 6.A-4. Adult Delta Smelt Upstream Movement Analysis Based on DSM2-PTM: Fate (Mean Percentage) of Particles by Release Location, Water Year Type, and Geographic Subregion (Upper San Joaquin River to Upper Sacramento River) After 30 Days

Release Location	Water Year Type	Upper San Joaquin River			Lower Sacramento River			Sacramento River Near Rio Vista			Cache Slough and Liberty Island			Sacramento River Ship Channel			Sacramento River Near Ryde			Upper Sacramento River		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Cache Sl. at Liberty Island (Node 323)	W	0.0	0.0	0.0 (0%)	1.4	1.8	0.4 (33%)	0.5	0.6	0.1 (24%)	11.2	12.5	1.3 (12%)	4.5	4.6	0.1 (2%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	0.0	0.0	0.0 (0%)	1.1	1.3	0.2 (17%)	0.8	0.8	0.0 (2%)	12.6	12.8	0.2 (2%)	7.9	7.9	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	0.0	0.0	0.0 (0%)	2.0	3.5	1.5 (72%)	0.4	0.7	0.3 (84%)	42.7	45.0	2.3 (5%)	17.1	16.6	-0.5 (-3%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	D	0.0	0.0	0.0 (0%)	1.8	2.0	0.2 (13%)	1.3	1.3	0.0 (1%)	49.2	51.7	2.5 (5%)	21.3	21.4	0.1 (0%)	0.0	0.0	0.0 (-100%)	0.0	0.0	0.0 (0%)
	C	0.0	0.0	0.0 (0%)	1.4	1.6	0.2 (16%)	0.8	0.8	0.1 (10%)	63.2	64.3	1.1 (2%)	27.2	26.8	-0.4 (-2%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (-100%)
Decker Island (Node 353)	W	0.0	0.0	0.0 (0%)	1.0	1.6	0.7 (67%)	0.1	0.2	0.1 (72%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	0.0	0.0	0.0 (0%)	0.7	0.8	0.1 (13%)	0.0	0.1	0.0 (8%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	0.0	0.0	0.0 (0%)	3.7	4.9	1.2 (33%)	0.6	0.7	0.1 (25%)	2.9	3.5	0.5 (18%)	0.1	0.1	0.0 (-14%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	D	0.0	0.0	0.0 (0%)	5.2	6.2	1.0 (19%)	1.8	2.3	0.5 (29%)	1.1	1.5	0.4 (36%)	0.0	0.0	0.0 (42%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (50%)
	C	0.0	0.0	0.0 (0%)	6.3	6.3	-0.1 (-1%)	3.9	4.0	0.1 (2%)	2.7	4.3	1.6 (59%)	0.1	0.1	0.0 (30%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (-100%)
Montezuma Slough (Node 420)	W	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (-83%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	D	0.0	0.0	0.0 (0%)	0.1	0.0	0.0 (-68%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	C	0.0	0.0	0.0 (0%)	0.2	0.1	-0.1 (-38%)	0.0	0.0	0.0 (-20%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
Chipps Island (Node 465)	W	0.0	0.0	0.0 (0%)	0.8	1.3	0.5 (57%)	0.1	0.1	0.1 (63%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	0.0	0.0	0.0 (0%)	0.4	0.5	0.1 (26%)	0.0	0.1	0.0 (8%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	0.0	0.0	0.0 (0%)	3.7	4.5	0.7 (19%)	1.0	1.1	0.1 (13%)	1.8	2.0	0.1 (7%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	D	0.0	0.0	0.0 (0%)	5.0	6.4	1.3 (26%)	1.9	2.5	0.6 (32%)	0.5	0.7	0.2 (45%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	C	0.0	0.0	0.0 (0%)	6.6	7.1	0.5 (7%)	3.9	4.2	0.3 (9%)	1.5	3.1	1.6 (104%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (-100%)	0.0	0.0	0.0 (0%)

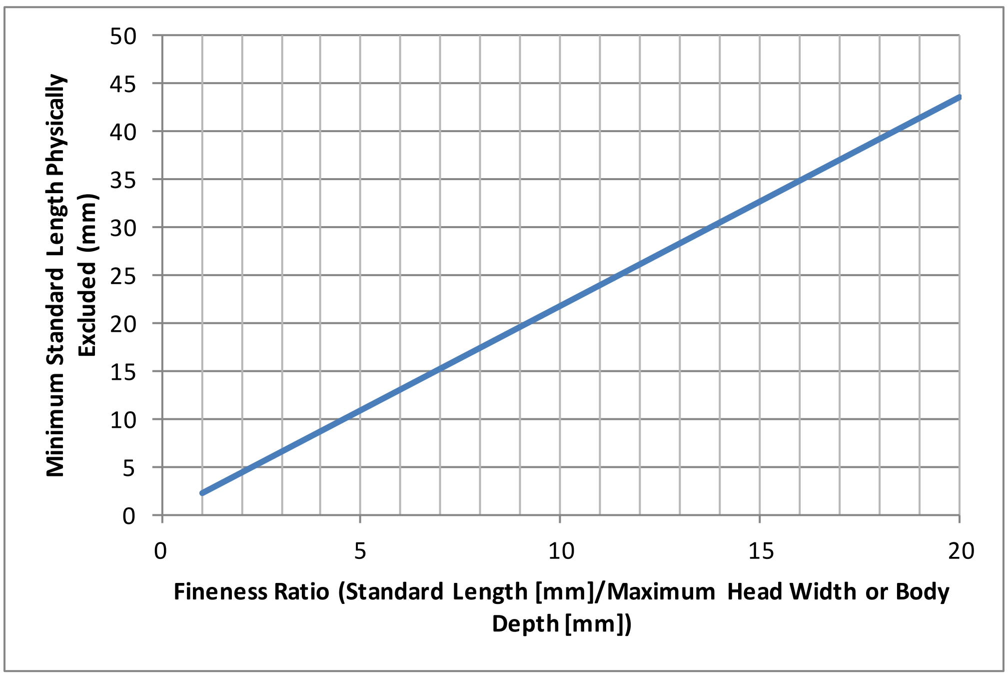
Note: Grey shading indicates that no particles had this fate for either the NAA or PA.

6.A.2.2 Screening Effectiveness Analysis

The size of larval and juvenile Delta Smelt theoretically vulnerable to entrainment through the proposed north Delta fish screens (i.e., passing through the screen) is a function of the slot opening of the screen mesh and the size (length and depth) of the fish (Turnpenny 1981; Margraf et al. 1985; Young et al. 1997). The analysis of the effectiveness of the north Delta intake screens in preventing entrainment through the proposed North Delta Diversion (NDD) fish screens was based on the proposed 1.75-millimeter (mm) smooth vertical wedgewire screen design. The minimum size (standard length) of Delta Smelt that would be excluded from entrainment was based on the equation originally formulated by Turnpenny (1981), as rearranged by Margraf et al. (1985) and presented by Young et al. (1997:19 (Figure 6.A-1):

$$SL = (0.06564 \times M + 1.199 \times M \times F)/(1 - 0.0209 \times M)$$

Where SL = standard length (mm), M = screen vertical opening size, F = fineness ratio (i.e., standard length/head width or body depth).



Source: Based on equation provided by Young et al. 1997.

Figure 6.A-1. Minimum Standard Length of Fish Physically Excluded by 1.75 mm Vertical Wedgewire Screens

For most species, head width would be smaller than body depth and, given the vertical openings of the proposed screens, would be the most appropriate denominator for the fineness ratio. Fineness ratios for Delta Smelt were calculated based on morphometric relationships presented by Young et al. (1997), specifically rearrangement of the formula predicting total length from standard length, followed by application of the formula predicting head width from total length[1].

$$\text{Total length (mm)} = (SL - 0.003)/0.84$$

$$\text{Head width (mm)} = -2.66 + (0.28 \times TL) - (0.004 \times TL^2) + (0.000028 \times TL^3)$$

Fineness ratios (standard length/head width) were then calculated for Delta Smelt from 20- to 80-mm SL in 0.1-mm SL increments, and the required vertical opening size for each size of Delta Smelt was estimated from rearrangement of the relationship between mesh size, standard length, and fineness ratio.

$$\text{Required vertical opening (mm)} = SL/(0.0209 \times SL + 0.06564 + 1.199 \times F)$$

This formula indicated that the proposed 1.75-mm screens would be expected to exclude Delta Smelt of approximately 20.45 mm (Figure 6.A-2). Thus, Delta Smelt larger than ~20-21 mm could be impinged but most likely not entrained all the way through the fish screens, whereas Delta Smelt less than ~20-21 mm long could be either impinged on or entrained all the way through the fish screens. For fish near 20 mm, the result would probably be mortality in either case, unless no water was being diverted through the screen at the time of screen contact. The potential for Delta Smelt to swim away from the screens after impingement would be expected to increase with increasing body size (above 20 mm), although this was not observed in experiments using 25-40-mm-long Delta Smelt (Swanson et al. 2005).

[1] The formula relating head width to standard length that is presented by Young et al. (1997) did not give results consistent with their Figure 1. Therefore it was necessary to first use the formula predicting total length from standard length, followed by the formula predicting head width from total length, in order to obtain a predicted head width for a given standard length.

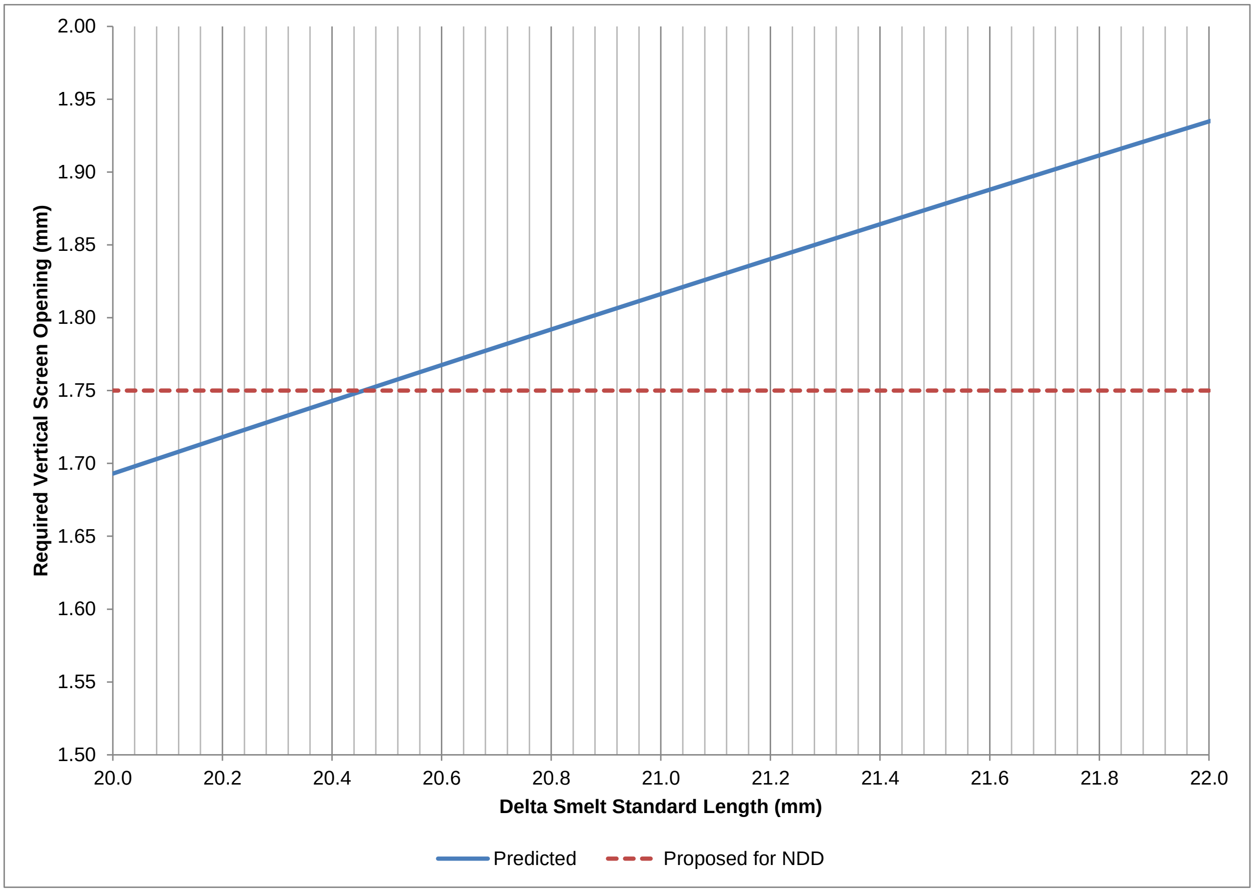


Figure 6.A-2. Predicted Vertical Screen Opening Required for Delta Smelt, in Relation to Proposed NDD Opening

6.A.2.3 Impingement and Screen Contact

The potential for effects of the proposed north Delta diversions in terms of injury and mortality caused by impingement and screen contact was assessed in a series of experiments conducted at the University of California, Davis (UC Davis) Fish Treadmill Facility (Swanson et al. 2004; 2005; White et al. 2007; Young et al. 2010). These studies examined the effects of various approach and sweeping velocities during daytime and nighttime at different temperatures on swimming behavior and screen interactions, injury and physiological stress indicators. The effects analysis of the proposed north Delta intake screens is qualitative because sweeping velocities near the screens have not been modeled with simulated operation of the screens. As described in Chapter 3, *Description of the Proposed Action*, the proposed NDD would include fish screens that are 1,350 feet long (intakes 2 and 5) or 1,110 feet long (intake 3). The screens would be operated to an approach velocity of 0.2 feet per second, which is often used as a criterion to protect Delta Smelt from excessive impingement.

The number of fish screen contacts and resulting injury and mortality was estimated for several different environmental conditions that represent a range that could occur at the proposed NDD screens. The calculations were made for the lengths of screen proposed at intakes 2, 3, and 5, with calculations made for day and night, at sweeping velocities between 0.1 and 2 feet per second. The analysis was standardized to a temperature of 12°C, which is representative of ambient water temperatures in February/March. Key terms in these analyses include approach velocity (water velocity towards and perpendicular to the screen face), sweeping velocity (water velocity parallel to the screen face), swimming velocity (velocity through the water but not over the bottom), and screen passage velocity (velocity of fish moving past the screen, either upstream or downstream). Note that the final quantity of interest (i.e., percentage mortality) in these analyses is estimated from a series of linked equations that explain different quantities of variation in the underlying experimental data and often comparatively low amounts of variation (e.g., less than 50 percent). The analyses do not propagate the uncertainty introduced from combining equations. Note also that the experiments upon which the equations are based were conducted in relatively benign laboratory conditions and do not account for environmental conditions that could influence fish swimming performance (e.g., water quality other than temperature, or reduced visibility during the day because of turbidity). In addition, the fish treadmill studies were conducted in a channel that measured approximately 0.44 meter deep, 1.2 meters wide, and 10.5 meters in circumference (Swanson et al. 2005); the NDD would be located in a river channel that is more than 100 meters wide, and the screens would be 12 to 17 feet tall (Chapter 3, *Description of the Proposed Action*).

Two of the analyses presented below (Section 6.A.2.3.1.1 *Adult Delta Smelt (Number of Screen Contacts)*; Section 6.A.2.3.1.2, *Juvenile and Adult Delta Smelt (Percentage Mortality)*) were based on an assessment methodology undertaken as part of the BDCP Fish Facilities Technical Team planning effort (Webb, pers. comm.). The other analysis (Section 6.A.2.3.1.3 *Adult Delta Smelt (Screen Passage and Survival)*) was adapted from an analysis provided by USFWS following review of an earlier draft of this BA.

As described in Section 3.2.2.2, *Fish Screen Design*, 22-foot-wide refugia could be provided between each of the six screen bay groups at the three intakes, which, if effective, could provide resting areas and predator refuge for Delta Smelt occurring near the intakes. However, given that the refugia are still in the conceptual design phase and there is uncertainty as to their effectiveness for Delta Smelt, the analyses presented here only account for the refugia by excluding the refugia length from the estimates of overall screen length at each intake.

6.A.2.3.1.1 Adult Delta Smelt (Number of Screen Contacts)

The screen contact rate has a positive correlation with physiological stress (measured as plasma cortisol) in adult Delta Smelt (Young et al. 2010). For adult Delta Smelt (fish greater than 5 centimeters [cm] SL), calculations were made of the number of contacts with a screen, based on the equations of Young et al. (2010). These experiments were conducted only during the day. The contact rate was calculated as follows:

Contact rate (contacts/fish/min) = 0.042 + 0.009 (approach velocity, cm/s) – 0.001 (sweeping velocity, cm/s); $r^2 = 0.421$

Total number of contacts was calculated as contact rate multiplied by exposure duration, which was calculated based on screen length and swimming velocity, with the latter estimation based on the equation of Young et al. (2010).

Swimming velocity (cm/s) = 14.283 + 0.459 (approach velocity, cm/s) + 0.117 (sweeping velocity, cm/s) – 0.003 (approach velocity × sweeping velocity, cm/s); $r^2 = 0.410$

6.A.2.3.1.2 Juvenile and Adult Delta Smelt (Percentage Mortality)

For juvenile and adult Delta Smelt (4.6–6.3 cm SL), calculations were made of percentage mortality based on the equations of Swanson et al. (2005). Note that "percentage mortality" refers only to the Delta Smelt occurring in the reach of the Sacramento River where the proposed NDD would be situated and, of those, only the ones attempting to move upstream past the intakes near the left (east) bank of the river.

> 48-hour % mortality (day) = -26.59 + 171.90 (contact rate, contacts/fish/min) + 1.31 (temperature, °C) + 1.04(approach velocity, cm/s); n= 56, r^2 = 0.4815, SEE = 13.31

> 48-hour % mortality (night) = -35.09 + 7.63 (contact rate, contacts/fish/min) + 1.75 (temperature, °C) + 2.16 (approach velocity, cm/s) + 0.05 (approach velocity × sweeping velocity, cm/s); n= 56, r^2 = 0.7667, SEE = 13.77

Contact rates in the above equations were calculated from the equations of Swanson et al. (2005).

> Contact rate (day, contacts/fish/min) = 0.0035 (approach velocity, cm/s) + 0.0001 (approach velocity × sweeping velocity, cm/s); n = 95, r^2 = 0.6454, SEE = 0.0556

> Contact rate (night, contacts/fish/min) = 0.0164 (approach velocity, cm/s) + 0.0002 (approach velocity × sweeping velocity, cm/s); n = 61, r^2 = 0.4315, SEE = 0.5405

Percentage mortality estimates assume a 2-hour screen exposure because this was the standard duration of the Fish Treadmill experiments. Mortality was adjusted to reflect estimated exposure duration. Exposure duration was estimated as a function of screen passage velocity, which was calculated from the equations of Swanson et al. (2005).

> Screen passage velocity (day, cm/s) = -12.11 + 0.92 (sweeping velocity, cm/s) + 1.32 (swimming velocity, cm/s); n = 87, r^2 = 0.9689, SEE = 3.78

> Screen passage velocity (night, cm/s) = -0.91 (sweeping velocity, cm/s) + 0.36 (swimming velocity, cm/s); n = 43, r^2 = 0.9794, SEE = 4.59

Screen passage velocity in the above equations was a function of swimming velocity, which again was estimated using the equations of Swanson et al. (2005).

> Swimming velocity (day, cm/s) = 11.24 + 0.24 (approach velocity, cm/s) + 0.09 (sweeping velocity, cm/s) + 0.37 (temperature, °C); n = 87, r^2 = 0.3412, SEE = 4.30

> Swimming velocity (night, cm/s) = 6.83 + 0.52 (approach velocity, cm/s) + 0.15 (sweeping velocity, cm/s); n = 87, r^2 = 0.8534, SEE = 2.13

6.A.2.3.1.3 Adult Delta Smelt (Screen Passage and Survival)

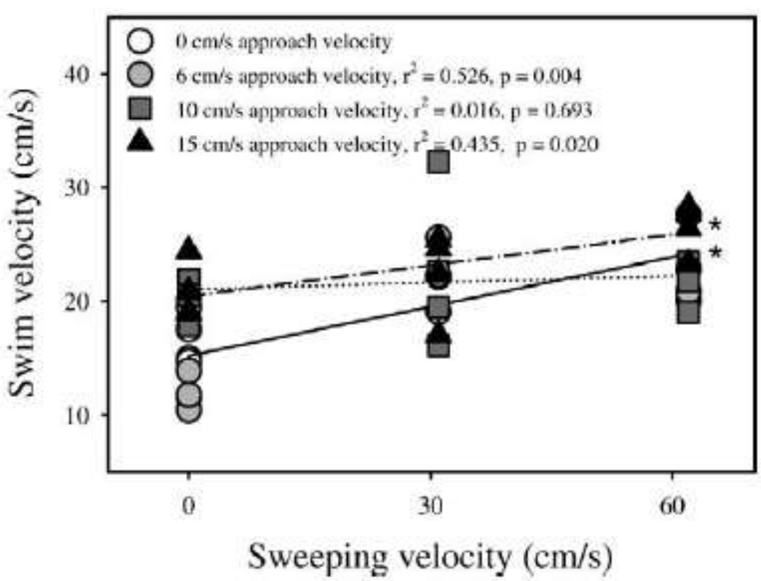
During the fall, the spatial distribution of the Delta Smelt population contracts due to seasonal increases in estuarine salinity (Feyrer et al. 2007). When it rains during the winter, the population expands its distribution in response to the increase in turbid fresh water (Sommer et al. 2011; Murphy and Hamilton 2013). This expansion is probably facilitated by numerous behaviors, but tidal surfing (changes in how the fish use channels when tides change) is one set of behavioral mechanisms that Delta Smelt can use to either stay in a desired location or to move rapidly

(Feyrer et al. 2013; Bennett and Burau 2015). As previously described in Section 6.A.2.1, *Migrating Adult Movement Upstream (DSM2-PTM)*, this effects analysis employed PTM using a simple tide surfing behavior originally described by Culberson et al. (2004) to evaluate the likelihood that adult Delta Smelt could tide surf to the proposed locations of the NDDs (see Section 6.A.2.1).

The results of the PTM analysis indicated that there was no measurable probability that tide surfing fish could ascend the Sacramento River even to Isleton, much less further upstream to the reach of river where the NDDs would be constructed. This makes intuitive sense for two reasons. First, the tidal energy extending up into Cache Slough is much greater than the tidal energy extending into the comparatively narrow mainstem channel. Second, both flood and ebb tide flows are usually moving downstream in the Sacramento River where the proposed NDDs would be built. Once the tides stop flowing in two directions, the standard tide surfing mechanisms would no longer work to move fish upstream. However, a few adult Delta Smelt do ascend the Sacramento River (Merz et al. 2011), in one robustly documented instance, even reaching Knight’s Landing, which is well beyond the reach of tidal influence (Vincik and Julienne 2012). The most parsimonious explanation for how Delta Smelt can accomplish this against strong water velocities is to do something they do less frequently further downstream – move toward the shoreline where water velocities are slower.

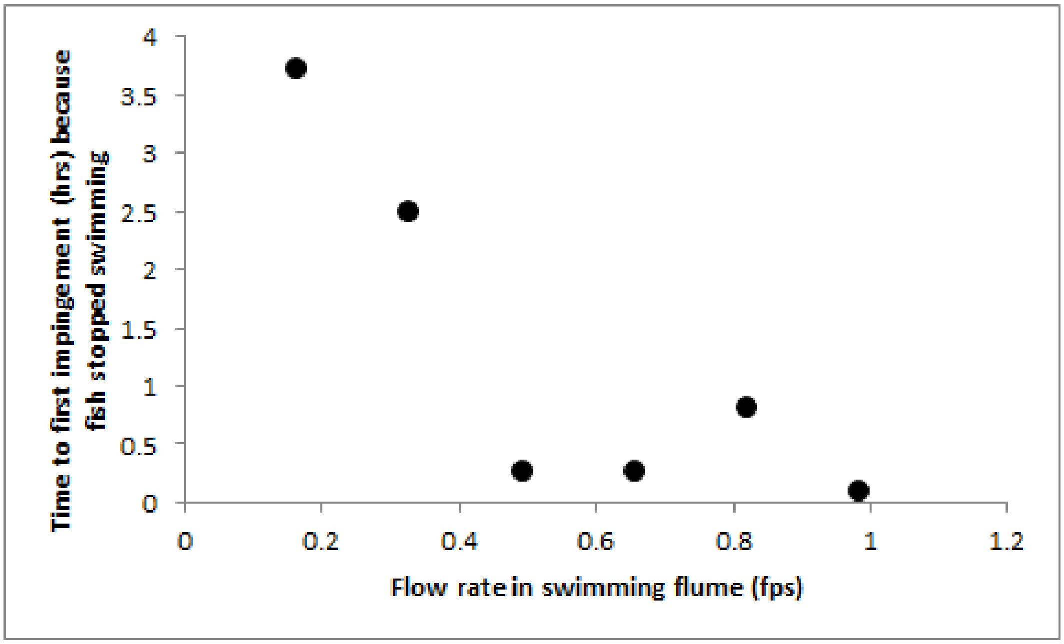
Once constructed, each of the NDDs will be a vertical wall of fish screens extending ~1,100-1,350 feet at a stretch along the east bank of the Sacramento River (see Chapter 3, Section 3.2.2.2, *Fish Screen Design*). If adult Delta Smelt attempt to move upstream along the east bank of the river, these areas will no longer have shoreline with relatively low velocity, requiring swimming against in-channel velocities if attempting to pass the screens. By virtue of small body size Delta Smelt are relatively “poor” swimmers (Swanson et al. 1998). In addition, they are non-continuous swimmers. This makes sense because they evolved in a high velocity tidal environment (as did their immediate ancestor, the surf smelt *H. pretiosus*) where it would be energetically wasteful for a small fish to swim against currents all the time.

Swanson et al. (1998) estimated that on average, the maximum sustainable swimming speed for Delta Smelt is 27.6±5.1 cm/s (0.91±0.17 ft/s), for about ten minutes. This estimate was not sensitive to fish length over the size range 30-70 mm (see Figure 1 of Swanson et al. 1998). Thus, for a Delta Smelt to swim upstream at all, the river velocity has to be less than their sustainable swimming speed. If the river velocity is higher than the sustainable swimming speed and Delta Smelt cannot escape the current, then they will be pushed back downstream. Young et al. (2010) found that sweeping velocities in the Fish Treadmill affected the swimming speed of adult Delta Smelt; when sweeping velocity was experimentally increased (analogous to river velocity), Delta Smelt increased their swimming speed (Young et al. 2010: Figure 2). However, the observed increases were very slight, and the mean swimming speed predictions from the equation produce even slower swimming speeds than the Swanson et al. (1998) results. Note the 1998 swimming speed estimate is very close to the maximum observed at the maximum sweeping velocity tested and therefore it provides an optimistic estimate of Delta Smelt’s swimming ability. If the average 2010 swimming speeds are substituted for the 1998 results, *then no adult Delta Smelt could ever pass the NDDs except when flows are too low to enable pumping*. Thus, it is acknowledged that calculations based on the 1998 swimming speed estimate will be inherently optimistic for three reasons. First, newer estimates suggest slower mean swimming speeds based on longer duration calculations (Young et al. 2010; Figure 2). Second, lacking information on how straight of a line Delta Smelt would swim in when trying to pass a long fish screen, it is necessary to make the assumption that they will swim in a perfectly straight line. Third, Delta Smelt are unlikely to swim continuously for lengthy periods of time when there is a current (Swanson et al. 1998; Figure 3), but for this analysis it was considered too speculative to try to adjust calculations based on such a nonlinear response developed under confined conditions to which the fish are not adapted. Thus, for the following analysis, the simplifying assumptions are made that the fish will swim past the fish screen in a straight line and that if they can swim the necessary distance in one hour or less that they will swim continuously except during the moments they are predicted to be impinged. The one-hour time step is reasonable because at the minimum channel velocity at which diversions were assumed to be allowable in the operations modeling (0.4 ft/s; see Appendix 5.A, Section 5.A.5.2.4.9, *North Delta Diversion Bypass Flows*, and Appendix 5.B, Section 5.B.2.3.5, *North Delta Diversion Operations*) Delta Smelt could theoretically swim upstream 1,110 feet in 0.60 hours and 1,350 feet in 0.74 hours (0.91 ft/s minus 0.4 ft/s = 0.51 ft/s "net" upstream swimming speed * 3,600 s/hr = 1,836 ft/hr). A similar calculation shows that Delta Smelt could possibly swim past a 1,350-foot-long fish screen in one hour when their net upstream swimming velocity was at least 0.375 ft/s. On the basis of the 0.91-ft/s maximum sustainable swimming speed, this would happen whenever Sacramento River velocity in front of the fish screens was less than 0.535 ft/s (or when Sacramento River flow was low enough that flood tide currents "reversed" the river flow and moved net currents in an upstream direction).



Source: Young et al. (2010: Figure 7).

Figure 6.A-3. Sweeping Velocity in the UC Davis Fish Treadmill Versus Swimming Velocity of Adult Delta Smelt During Two-Hour Experiments



Source: Swanson et al. (1998: Table 1).

Figure 6.A-4. Flow rates Experienced by Delta Smelt In A Swimming Flume Versus Time Until the Fish Were First Impinged Against the Back of the Flume Because They Had Stopped Swimming

The best available information on what Sacramento River velocities might be in front of the NDDs is from the velocity gauge in the river at Freeport (CDEC gauge FPT, sensor 21). These data were downloaded at an hourly time step for the months of December-June based on Delta Smelt collections in the area described in Appendix 6.A. The Freeport velocity data were available for 1990-2000. The hourly river velocities were converted into net upstream swimming velocities for adult Delta Smelt: 0.91 ft/s minus measured velocity, and the results were summarized using a histogram. This analysis was also repeated using only December-March data, which based on the fish salvage facilities in the south Delta, represents a time of year that most adult Delta Smelt "migration" occurs (Grimaldo et al. 2009).

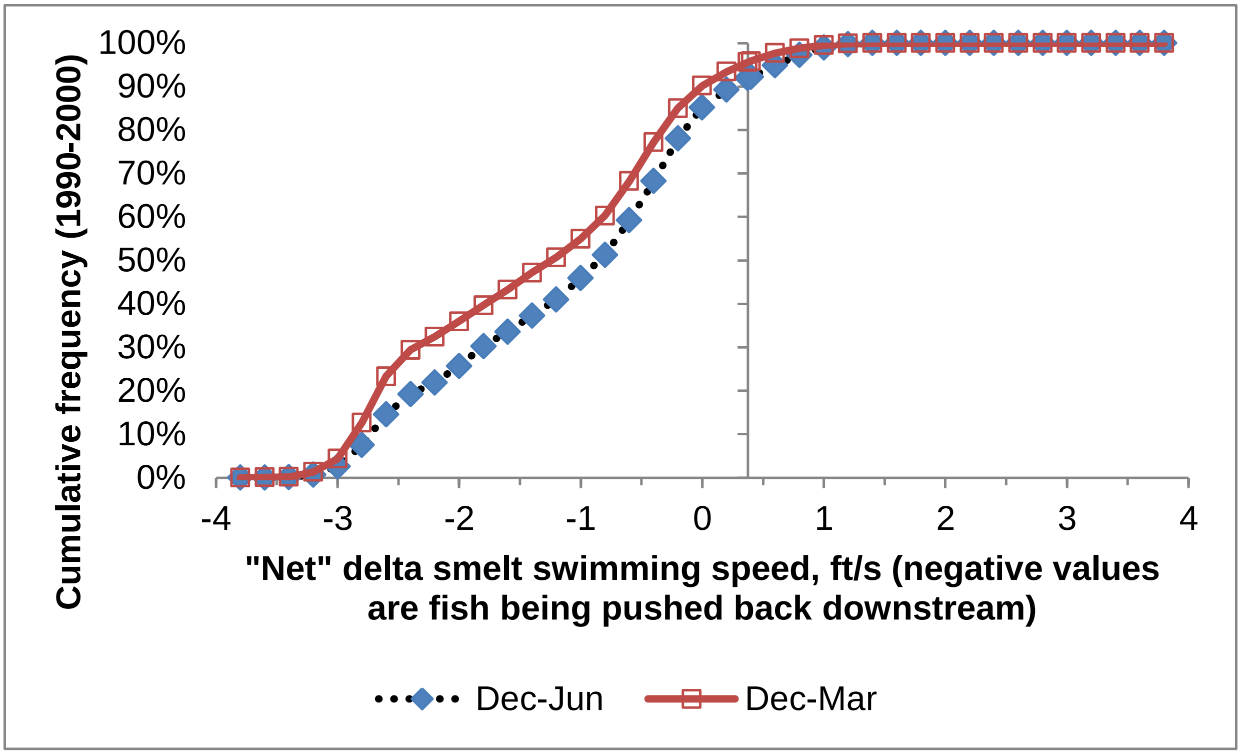


Figure 6.A-5. Cumulative Frequency Distributions of Estimated Swimming Velocities of Adult Delta Smelt in the Sacramento River (0.91 ft/s minus measured velocity at Freeport) for December-June, 1990-2000 (blue symbols with black line) and December-March, 1990-2000 (red line and symbols). Note that the y-axis crosses the x-axis at 0.375 ft/s, the velocity at which Delta Smelt could swim far enough in one hour to theoretically pass a 1,350-foot-long fish screen

Hourly river velocities slow enough that Delta Smelt could swim upstream more than 1,350 feet in an hour occurred with a frequency of 0.081 during December-June 1990-2000 and 0.044 during December-March 1990-2000 (Figure 6.A-5). This analysis was repeated using a swimming speed of 19 cm/s (0.62 ft/s), which was loosely derived from Young et al. (2010). The use of this slower swimming speed had the obvious effect of making estimates of successful fish passage even rarer; 0.042 and 0.018 for December-June and December-March, respectively (results not shown).

February 1 – 27, 1991 was a low-flow period in a drought year in which data were fairly complete and in-channel river velocities were frequently slow enough (based on the assumptions described above) to enable Delta Smelt to move upstream at rates exceeding 1,350 ft/hr. Therefore, this time period was used to develop estimates of survival rates of Delta Smelt passing the proposed fish screens using the daytime mortality equation provided by Swanson et al. (2005). To the extent that Freeport velocity represents a bypass flow velocity in front of the NDD fish screens, during February 1991, hourly river velocities were high enough to allow NDD pumping 72 percent of the time (based solely on the 0.4 ft/s velocity criterion assumed for modeling purposes, and not accounting for any other NDD operations considerations), but the percentage of time that pumping could occur *and* Delta Smelt could theoretically pass the screen was only 8.0 percent - comparable to the longer term fraction shown in Figure 6.A-5. The analysis of mortality was restricted to these 8.0 percent of observations because it was assumed that river velocities exceeding the maximum sustained swimming speed of Delta Smelt will prevent the fish from even trying to pass the screen, and that river velocities that Delta Smelt can only very slowly swim upstream against will likewise dissuade fish from attempting to pass the screen or cause 100 percent mortality of the individual fish that attempt it under those conditions. Note that these fates are accounted for by the large fractions of impassable velocities shown in Figure 6.A-5.

The linear regression equation describing the estimated mortality from the fish treadmill experiments (Swanson et al. 2005) was the same as the one used for the analysis of daytime mortality presented in Section 6.A.2.3.1.2, *Juvenile and Adult Delta Smelt (Percentage Mortality)*:

> 48-hour % mortality (day) = -26.59 + 171.90 (contact rate, contacts/fish/min) + 1.31 (temperature, °C) + 1.04(approach velocity, cm/s); n= 56, r^2 = 0.4815, SEE = 13.31

As previously noted, Swanson et al. (2005) also developed an equation for night time exposures that predicts a lower mortality rate. This equation was not used because several ambitious assumptions about swimming speed had already been made in the calculations and because data were lacking to indicate that Delta Smelt actively migrate at night. Freeport water temperature data (CDEC gauge FPT, sensor 25) for February 1 – 27, 2010-2015, were downloaded to generate a range of likely water temperatures during which Delta Smelt would be expected to ascend the Sacramento River.

As previously described, the screen contact rate is a linear regression function of the approach and sweeping velocities:

> Contact rate (contacts/fish/min) = 0.042 + 0.009 (approach velocity, cm/s) – 0.001 (sweeping velocity, cm/s); r^2 = 0.421

The Freeport velocity data were used to represent the sweeping velocity required for the calculation of mortality, and the approach velocity in both equations was assumed to be 0.2 ft/s (6.1 cm/s) if Freeport velocity equaled or exceeded 0.4 ft/s (12.2 cm/s) and zero otherwise, consistent with the modeling assumption that no pumping would be allowed when the bypass velocity criterion was not met.

The estimated probability that an individual Delta Smelt would successfully pass the downstream-most NDD screen was estimated as:

$P = U*S$

Where, *P* is the probability of successful passage, *U* is the probability water velocity was slow enough that an average Delta Smelt could swim at least 1,350 feet upstream in one hour or less (described above to range from 0.044 to 0.081), and *S* is the survival of Delta Smelt passing the screen in the event they could. Survival was derived from the predictions of the 48-hour mortality equation (Swanson et al.2005) presented above as 1-(mortality/100); variation in *S* was generated using variation in upstream swimming distances of Delta Smelt derived from variation in Freeport velocity (1990-2000) and using the six years of hourly water temperature data described above (2010-2015).

6.A.2.4 Compensation for Potential Reduced Access to Critical Habitat Upstream of NDD

The analysis described in Section 6.A.2.3.1.3, *Adult Delta Smelt (Screen Passage and Survival)*, suggested that Delta Smelt attempting to migrate upstream past the NDD along the east bank of the Sacramento River would largely be unable to do so because of loss of lower velocity habitat (see discussion in Chapter 6, Section 6.1.3.2.2.1, *Migrating Adults (December-March)*). A preliminary analysis of aerial photography estimated that there are 55 acres of sandy beach habitat from the lowermost extent of intake 5 to the upstream extent of Delta Smelt critical habitat (the I Street Bridge in Sacramento; the upstream limit of the statutory Delta). DWR proposes to provide compensation for the 55 acres of sandy beach critical habitat which may be less accessible because of the NDD effects on water velocity. The initial estimate of 55 acres would be refined with field surveys.

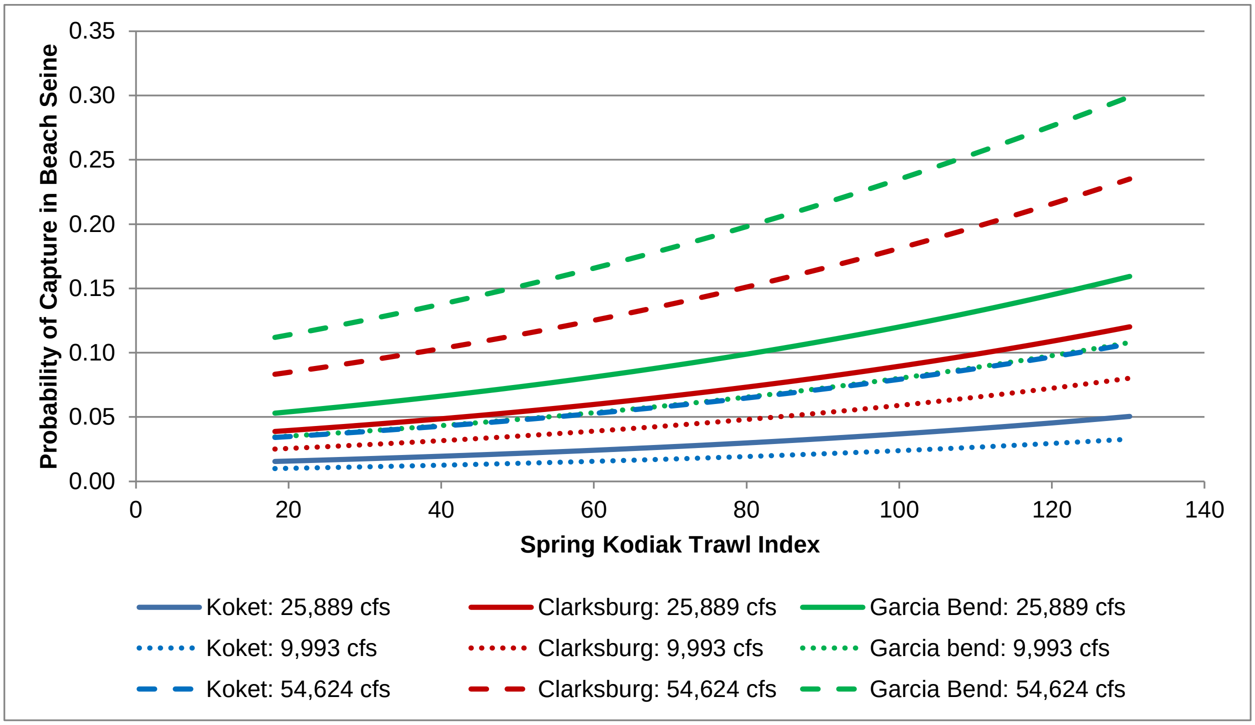
Given the potential for Delta Smelt to access critical habitat upstream of the NDD by using lower velocity areas on the west bank of the river, near the channel bottom, or within the refugia along the intakes, DWR proposes, subject to concurrence by USFWS and DFW, to adjust downward the required compensation if there is evidence that Delta Smelt are using upstream habitats to a similar extent as during the period prior to construction and operation of the NDD, based on the existing beach seine sampling program. An illustration of a potential approach to determine whether upstream access has been affected after construction of the NDD is provided herein.

It was hypothesized that the probability of capture of adult (≥ 60 mm) Delta Smelt in beach seines would be related to overall population size (represented by the Spring Kodiak Trawl index, for which estimates are available from 2004 to 2015; see ftp://ftp.delta.dfg.ca.gov/Delta%20Smelt/MEMO2015%20SKT%20Delta%20Smelt%20Index.pdf), and could also be affected by Sacramento River flow (e.g., influencing the ability to move upstream successfully, or as an index of cues stimulating upstream migration), as represented by mean daily December-March Freeport flow (DAYFLOW data, available up to water year 2014; see http://www.water.ca.gov/dayflow/output/Output.cfm). Examination of beach seine data for sites along the Sacramento River from river mile 17 (Isleton; station SR017E) to river mile 62 (Sand Cove; SR062E); American River near its mouth (AM001S); and Steamboat Slough near its head (SS011N), showed that three locations had more consistent occurrence of small numbers of Delta Smelt: Koket (SR024E, near Ryde, i.e., downstream of the NDD), Clarksburg (SR043E, directly across from intake 3), and Garcia Bend (SR049E, upstream of the NDD) (Table 6.A-5).

Table 6.A-5. Summary of December-May Adult Delta Smelt (≥ 60 mm) Catch Per Seine and Frequency of Occurrence at Koket, Clarksburg, and Garcia Bend

Water Year	Koket (SR017E)			Clarksburg (SR043W)			Garcia Bend (SR049E)		
	Number of Samples	Catch Per Seine	Frequency of Occurrence	Number of Samples	Catch Per Seine	Frequency of Occurrence	Number of Samples	Catch Per Seine	Frequency of Occurrence
2004	26	0.31	0.04	25	0.44	0.16	35	0.43	0.11
2005	25	0.00	0.00	24	0.17	0.08	38	0.47	0.11
2006	17	0.18	0.06	24	0.08	0.04	31	0.10	0.03
2007	21	0.00	0.00	24	0.00	0.00	32	0.03	0.03
2008	20	0.00	0.00	19	0.00	0.00	26	0.04	0.04
2009	26	0.00	0.00	26	0.08	0.04	29	0.14	0.07
2010	24	0.08	0.04	26	0.88	0.08	33	0.09	0.06
2011	24	0.08	0.08	20	0.45	0.10	35	0.71	0.20
2012	25	0.12	0.04	24	0.38	0.08	34	0.97	0.15
2013	24	0.00	0.00	24	0.00	0.00	43	0.00	0.00
2014	24	0.00	0.00	26	0.42	0.04	66	0.09	0.05
Source: http://www.fws.gov/lodi/jfmp/									

Generalized linear modeling (GLM) was undertaken of 920 beach seine samples taken during December-May at these three locations, to assess the probability of occurrence (presence/absence: logit link function, binomial distribution) of Delta Smelt adults as a function of SKT index, mean December-March Freeport flow, and station. Delta Smelt adults occurred in 51 of these samples. A series of GLMs was undertaken, including a full model (all main effects, all two-way interactions, and the three-way interaction) and reduced sets of models, including an intercept-only model. The most parsimonious model with the lowest Akaike's Information Criterion (AIC) included all three main effects, and had an area under the receiver operating curve of 0.69, which is close to the lower end of the range (0.7-0.8) for which discrimination between presence and absence is considered acceptable (Hosmer and Lemeshow 2000: 162). This GLM showed that Delta Smelt adults were most likely to be caught at Garcia Bend and least likely to be caught at Koket, with Clarksburg intermediate; in addition, capture probability increased with increasing SKT index and Freeport flow (Figure 6.A-6).



Note: The Freeport flows included in the plot represent the minimum, maximum, and mean daily flow for December–March 2004–2014.

Figure 6.A-6. Predicted Probability of Capture of Adult Delta Smelt During December-May 2004–2014 as a Function of Freeport Mean Daily December–March Flow and Spring Kodiak Trawl Index

It is proposed that the GLM[2] be used to predict the capture frequency of Delta Smelt at Garcia Bend as a function of observed Freeport flow and SKT index, following construction and operation of the NDD. Should the observed frequency of capture be within the 95% confidence interval for the prediction (Figure 6.A-7), given the conditions for that year, this would be taken to indicate that there had not been a significant effect of the NDD on upstream migration. DWR would then negotiate with the fish and wildlife agencies (USFWS, CDFW) to adjust downward the 55 acres of initially proposed mitigation.

[2] Given the number of years until construction and operation of the NDD, the GLM could also be refined with additional years of data.

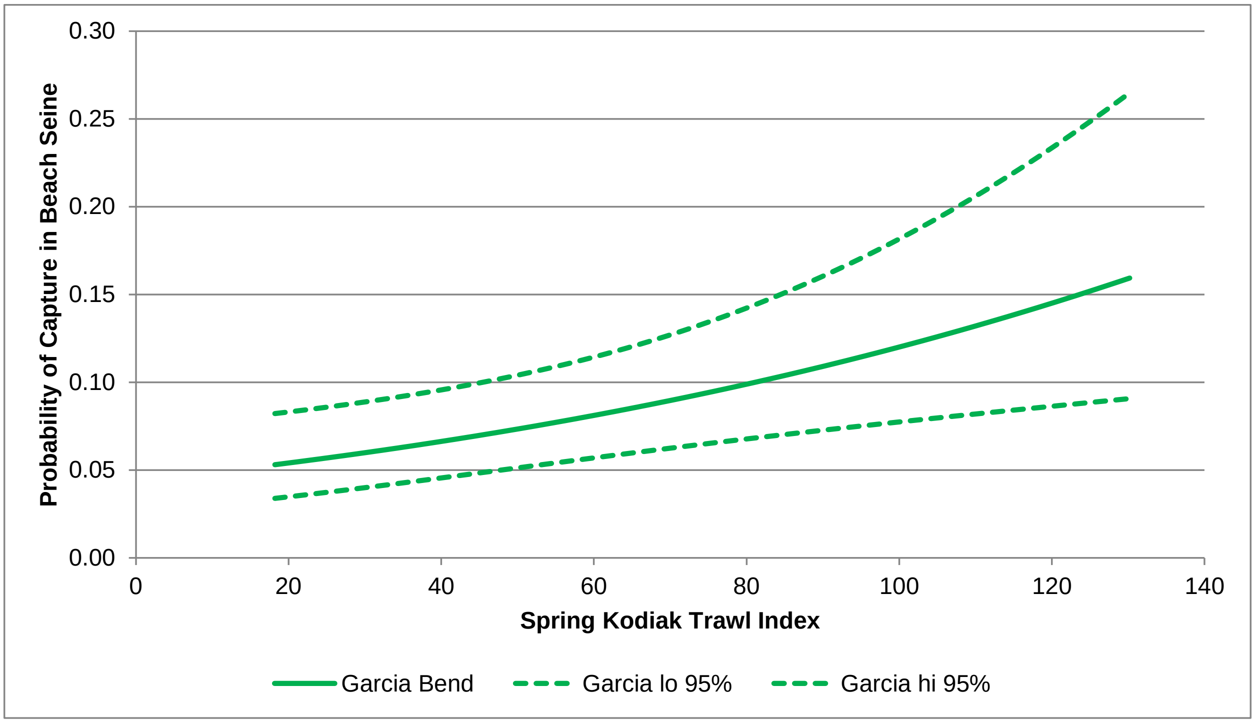


Figure 6.A-7. Predicted Probability of Capture of Adult Delta Smelt During December–May 2004–2014 as a Function of Freeport Mean Daily December–March Flow of 25,889 cfs and Spring Kodiak Trawl Index, with 95% Confidence Interval

6.A.3 South Delta Exports

6.A.3.1 USFWS Proportional Loss Equations

The proportion of the Delta Smelt population lost to entrainment at the south Delta export facilities was estimated for the various modeling scenarios with the regression equations used by the U.S. Fish and Wildlife Service (USFWS) (2008). The regression equations were based on the estimates of proportional entrainment by Kimmerer (2008), which were disputed and subsequently revised (Kimmerer 2011; Miller 2011). They are being revisited further in the Collaborative Science and Adaptive Management Program (CSAMP) process (see discussion below). Kimmerer's (2008) original estimates of entrainment loss had large confidence limits, which Kimmerer (2008:24) noted could be reduced by additional sampling. Since Kimmerer's paper was published, it has been recognized that turbidity plays a major role in the salvage of Delta Smelt, particularly in the adult stage (Grimaldo et al.2009). Thus, some of the uncertainty alluded to above is caused by the lack of turbidity as a predictor in Kimmerer's model. In addition, Miller (2011) assessed the explicit and implicit assumptions of Kimmerer's estimation methods and surmised that for estimates of adult proportional entrainment, there were eight assumptions of which three may have biased the estimates upward, one may have estimated the bias downward, and the remainder would not have resulted in bias. For larval-juvenile entrainment, Miller (2011) suggested that of 10 assumptions made by Kimmerer (2008), eight would have resulted in upward bias and two would not have resulted in bias. Miller (2011) suggested methodological adjustments for four of the assumptions that could have resulted in bias of adult and juvenile proportional entrainment estimates, but was not able to quantify adjustments for eight of the potential assumptions leading to (upward) bias. In response to the quantifiable biases suggested by Miller (2011), Kimmerer (2011) concurred with one (leading to a downward adjustment of his adult loss estimates by 24% [by multiplying by 0.76]; see detail below in Section 6.A.3.1.1, *Adults*) and rejected the others. A number of assumptions that may introduce upward bias remain unresolved and contribute to uncertainty in the estimates. At this time, there is no reliable way to forecast future turbidity, and therefore, the assumption is made that, on average, or across years, relative adult entrainment risk for comparison across model scenarios can be reasonably reflected using predictions of Old and Middle River (OMR) flow based on the USFWS (2008) equation. Similarly, it is assumed that the relative risk of larval-juvenile entrainment in the south Delta can be characterized by using predictions of X2 and OMR flow per the equation developed by USFWS (2008). The equations and the adjustment are described further below.

Although much is known about the factors that affect entrainment of Delta Smelt, there remains uncertainty in a number of key aspects. Further investigation of the factors that influence entrainment is being undertaken during studies prompted by the CSAMP (Collaborative Adaptive Management Team [CAMT] 2014). The CSAMP was launched following a decision by the United States District Court for the Eastern District of California on April 9, 2013, issued in response to a motion to extend the court-ordered remand schedule for completing revisions to the NMFS (2009) and USFWS (2008) biological opinions (BiOps). Under the CSAMP, CAMT has the mission of working to develop a robust science and adaptive management program that will inform Central Valley Project (CVP) and State Water Project (SWP) operations, particularly with respect to Delta operations. Key questions and possible investigative approaches related to entrainment are summarized in Table 6.A-6. Knowledge gained from these investigations will inform future refinement of operations to protect Delta Smelt, which could then be implemented under the No Action Alternative (NAA) and the PA.

Table 6.A-6. Key Questions and Possible Investigative Approaches to Address Entrainment Management as Part of the CAMT OMR/Entrainment Work Plan

Key Questions	Possible Investigative Approaches
What factors affect adult Delta Smelt entrainment during and after winter movements to spawning areas? a. How should winter “first flush” be defined for the purposes of identifying entrainment risk and managing take of Delta Smelt at the south Delta facilities? b. What habitat conditions (e.g., first flush, turbidity, water source, food, time of year) lead to adult Delta Smelt entering and occupying the central and south Delta?	Summarization of environmental and fish distribution/abundance data (e.g., FMWT, SKT). Multivariate analyses and modeling (e.g., 3D particle tracking) to examine whether fall conditions affect winter distribution. Completion of First Flush Study analyses. The Delta Conditions Team (DCT) is currently developing a scope of work to use turbidity modeling to examine various “first flush” conditions, expected entrainment risks, and potential preventative actions that could be taken to reduce entrainment, consistent with key question (a). The DCT could also conduct analyses to address key question (b).

Key Questions	Possible Investigative Approaches
What are the effects of entrainment on the population? a. What is the magnitude (e.g., % of population) of adult and larval entrainment across different years and environmental conditions? b. How do different levels of entrainment for adults and larvae affect population dynamics, abundance, and viability?	a. Application of different models (e.g., individual based models, life history) to estimate proportional entrainment. A direct approach to addressing question (a) has been proposed by Kimmerer 2008, as modified in 2011. This or a derivative approach should be explored as a means to directly estimate the proportional entrainment that has occurred in recent years. Apply to as much of historical record as possible. b. Application of different models (e.g., IBM, life history, population viability analysis [PVA]) to simulate effects on population dynamics, abundance, and variability.
How many adult Delta Smelt and larval/post-larval Delta Smelt are entrained by the water projects?	Workshop or expert panel review. Testing of new field methodologies such as SmeltCAM. Gear efficiency and expanded trawling experiments. Evaluation of alternative models to estimate abundance, distribution and entrainment.
What conditions prior to movement to spawning areas affect adult Delta Smelt entrainment? Is there a relationship between Delta Smelt distribution and habitat conditions (e.g., turbidity, X2, temperature, food) during fall and subsequent distribution (and associated entrainment risk) in winter?	Summarization of environmental and fish distribution/abundance data (e.g., FMWT, SKT). Multivariate analyses and modeling (e.g., 3D particle tracking) to examine whether fall conditions affect winter distribution. Completion of first flush study analyses.
What factors affect larval and post-larval Delta Smelt entrainment? a. How does adult spawning distribution affect larval and post-larval entrainment? b. What conditions (e.g., first flush, spawning distribution, turbidity, water source, food, time of year) lead to larvae and post-larvae occupying the central and south Delta?	Summarization of environmental and fish distribution/abundance data. Statistical analysis and modeling (e.g. 3D PTM) of effects of adult distribution (e.g., SKT) on larval (e.g., 20 mm) distributions. Summarization of environmental and fish distribution/abundance data (e.g., 20 mm). Multivariate analyses/modeling to identify conditions promoting occupancy of central and south Delta.
What new information would inform future consideration of management actions to optimize water project operations while ensuring adequate entrainment protection for Delta Smelt? a. Can habitat conditions be managed during fall or early winter to prevent or mitigate significant entrainment events? b. Should habitat conditions (including OMR) be more aggressively managed in some circumstances as a preventative measure during the upstream movement period (e.g., following first flush) to reduce subsequent entrainment?	Synthesis of available information and study results by CAMT Entrainment Team, designated expert panel, or both. Consultation with regulatory agencies and operators about the feasibility of different actions.
Source: Collaborative Adaptive Management Team (2014).	

6.A.3.1.1 Adults

The proportion of the adult Delta Smelt population lost to entrainment at the south Delta export facilities was estimated using estimates of Old and Middle river flow.

[proportional] adult entrainment loss = 6.243 – 0.000957*OMR Flow (December–March).

It is acknowledged that this approach does not fully encompass all factors related to entrainment loss, but that is primarily because doing so would render the estimates even less reliable. These factors would require forecasts of predictor variables that cannot be accurately forecasted (e.g., turbidity, Delta Smelt relative abundance). Estimates of proportional entrainment loss solely based on OMR flow would be overestimates if turbidity in the south Delta was not high enough to attract Delta Smelt into the area at the time of appreciably negative OMR flow or if abundance and distribution continue to be diminished. In addition, some uncertainty is introduced by using a regression that is based on point estimates of entrainment, which themselves have broad confidence intervals in some cases (Kimmerer 2008). Potential biases in the method are common to both scenarios examined in this effects analysis, although it is unknown the extent to which this affects the relative comparison of scenarios.

6.A.3.1.2 Larvae/Juveniles

For larval/juvenile Delta Smelt, the USFWS (2008) regression estimating percentage entrainment as a function of X2 and OMR flows was used to compare NAA and PA scenarios. The relevant portions of the development of the regression described by USFWS (2008: 220) are as follows (section formatting has been applied to highlight the equation):

> Kimmerer (2008) proposed a method for estimating the percentage of the larval-juvenile Delta Smelt population entrained at Banks and Jones each year. These estimates were based on a combination of larval distribution data from the 20 mm survey, estimates of net efficiency in this survey, estimates of larval mortality rates, estimates of spawn timing, particle tracking simulations from DWR's DSM2 PTM, and estimates of Banks and Jones salvage efficiency for larvae of various sizes. Kimmerer estimated larval-juvenile entrainment for 1995–2005. We used Kimmerer's entrainment estimates to develop multiple regression models to predict the proportion of the larval-juvenile Delta Smelt population entrained based on a combination of X2 and OMR. Using Kimmerer's method, larval-juvenile [entrainment] is predicted to be 0 during periods of very high outflow. For instance, Kimmerer predicted entrainment loss was 0% in 1995 and 1998. For simplicity, we estimated the relationship between X2, OMR, and larval-juvenile entrainment without 1995 and 1998 in the model because the relationship between these variables is linear when only years that had entrainment higher than 0 were modeled. [W]e developed two separate models, one for the March–June averaging period and one for the April–May averaging period. The reason for using two spring averaging periods was to demonstrate that the conclusions are robust with regard to choice of averaging period; the predicted entrainment is very similar. The equations are:
>
> March–June % entrainment = (0.00933*March–June X2) – (0.0000207*March–June OMR) – 0.556
>
> and
>
> April–May % entrainment = (0.00839*April–May X2) – (0.000029*April–May OMR) – 0.487.

> The adjusted R^2 on these equations are 0.90 and 0.87, respectively. …Because the equations were based only on data that had non-zero entrainment, they predict entrainment proportions are negative during periods of very high outflow. The negative entrainment predictions were changed to 0% before summary analysis.

For this effects analysis, both regressions were used. As noted for the adult regression analysis, some uncertainty is introduced by using a regression that is based on point estimates of entrainment, which themselves sometimes have broad confidence intervals (Kimmerer 2008). Note that the regressions actually give the proportion of the population entrained (0–1, as opposed to the percentage). Average OMR flows for the months of March–June and April–May were obtained from CALSIM modeling of the 1922–2003 water-year simulation period; these flows were averaged by water year. X2 was also obtained from CALSIM results. Because X2 output in CALSIM for a given month actually indicates X2 at the end of the previous month, the CALSIM output months for X2 averaged for the analysis in each water year were April–July, which were assumed to represent the March–June period. Consistent with USFWS (2008: 220), estimates of negative entrainment were changed to 0 before data summary.

6.A.3.2 Larval Entrainment (DSM2-PTM)

The larval-juvenile Delta Smelt proportional loss equation for entrainment at the south Delta export facilities described above is concordant with predictions made using steady-state flows in an older version of DSM2 PTM (Kimmerer 2008). For the present effects analysis, the most recent version of DSM2 PTM was used in the effects analysis to estimate the proportional entrainment of Delta Smelt larvae by various water diversions in the Action Area (i.e., the south Delta export facilities, the NDD, and the NBA Barker Slough Pumping Plant). Further information is provided in Appendix 5.B, Section 5.B.3.3, *DSM2-PTM for Evaluating Larval Delta Smelt.* This second approach assumed that the susceptibility of Delta Smelt larvae can be represented by entrainment of passive particles, which USFWS considers likely based on existing literature (Kimmerer 2008, 2011). Results of the PTM simulations do not represent the actual entrainment of larval Delta Smelt that may have occurred in the past or would occur in the future, but rather should be viewed as a comparative indicator of the relative risk of larval entrainment under NAA and PA scenarios. For purposes of this effects analysis, those particles that were estimated to have entered the various water diversion locations included in the PTM outputs (e.g., south Delta export facilities, NDD, and NBA) are characterized as having been entrained. The latest version of DSM2-PTM allows agricultural diversions to be excluded as sources of entrainment (while still being included as water diversion sources): for this effects analysis, these agricultural diversions were excluded, given the relative coarseness of the assumptions related to specific locations of the agricultural diversions, the timing of water withdrawals by individual irrigators, and field observations that the density of young Delta Smelt entrained by these diversions is relatively low (Nobriga et al. 2004).

Delta smelt starting distributions used in the PTM larval entrainment analysis were based on the CDFW 20 mm larval survey and were developed in association with M. Nobriga (USFWS Bay-Delta Office). This method paired observed Delta Smelt larval distributions from survey data with modeled hydraulic conditions from DSM2 PTM. Each pair was made by matching the observed Delta outflows of the first 20 mm survey that captured larval smelt (16 years of 20 mm surveys, 1995–2011) with the closest modeled mean monthly Delta outflow for the months of March to June in the 82 years of PTM simulations.

The 20 mm survey samples multiple stations throughout the Delta fortnightly. The average length of Delta Smelt caught during each survey was averaged across all stations (8–10 surveys per year) (Table 6.A-7). The survey with mean fish length closest to 13 mm was chosen to represent the starting distribution of larval smelt in the Delta for that particular year (Table 6.A-7). A length of 13 mm was chosen in order to represent a consistent period each year with respect to size/age of Delta Smelt larvae, while accounting for the mean size by survey across all years and the general pattern of more efficient capture with greater size. Catch efficiency changes rapidly for Delta Smelt larvae as they grow (see Figure 8 of Kimmerer 2008); the choice of 13 mm represents a compromise between larger larvae/early juveniles (e.g., ≥ 20 mm) that are captured more efficiently but which may have moved too far to accurately represent starting distribution and likely would be behaving less like passive particles, and smaller larvae (e.g., < 10 mm) that are not sampled efficiently enough to provide a reliable depiction of starting distribution. During the period included in the analysis (1995–2011), the fourth survey was selected most frequently (range between the first and fifth surveys).

Once a survey date was chosen for a given year, the actual Delta Smelt catch during this survey was examined by station number (Table 6.A-8). Stations downstream of the confluence of the Sacramento and San Joaquin River confluence (in Suisun Bay and Suisun Marsh) were eliminated, as particles originating in these areas would not be subject to entrainment in the Delta and the PTM is better suited for the channels of the Delta than for the open-estuary environment of Suisun Bay. Several stations in the Cache Slough area also were not included as they were introduced in 2008 and did not have data for the entire period from which starting distributions are calculated. A list of stations and counts of Delta Smelt are provided in Table 6.A-8, along with the fish count not used to calculate the starting distribution, as a percentage of total fish caught during a given survey. Note that the percentage of larvae collected downstream of the Sacramento–San Joaquin confluence varies from zero to almost 100%, depending on water year. For example, in 2002 (survey 4), with relatively low outflow of approximately 13,500 cubic feet per second (cfs), only 2.5% of larvae were downstream of the confluence (Table 6.A-8). In contrast, over 70% of larvae were downstream in 1998 (survey 4), with outflow of nearly 70,000 cfs (Figure 6.A-9). These percentages were used to adjust the percentage of particles (particles representing larvae) that would be considered susceptible to entrainment.

Delta smelt counts per station were then divided by the contributing area of a given station in acres (Table 6.A-9), to remove spatial disparities, and percentages of the total number of Delta Smelt caught were calculated for each of the main areas included in the analysis. The final annual starting distributions then were established by evenly distributing assigned percentages to each DSM2 PTM node (i.e., model particle insertion points) in a given area (Table 6.A-10).

Each of the 328 months included in the PTM (i.e., March-June in 82 years) was matched to the closest starting distribution based on the average monthly Delta outflow. Average monthly Delta outflow for the months modeled by PTM hydro periods were based on CALSIM (NAA scenario) (Table 6.A-8). Average monthly Delta outflow during the selected 20 mm survey period was calculated from DAYFLOW. If the selected survey period spanned two months (usually April–May), the applied outflow was for the month when most of the sampling occurred. The correspondence between the modeled Delta outflow and the applied starting distribution outflow from the 20 mm survey was reasonable: the mean difference was 4% (median = 1%), with a range from -221% (modeled Delta outflow of over 290,000 cfs in March 1983 matched with historical outflow of 90,837 cfs during survey 1 of 1995) to +58% (modeled Delta outflow of 4,000 cfs in several months matched with historical outflow of 9,482 cfs during survey 4 of 2008). Analysis of the PTM outputs was then done by multiplying the percentage of particles entrained from each release location by the applicable starting distribution percentage summarized in Table 6.A-9. Results were summarized for 30-day particle tracking periods as the percentage of particles being entrained at the NDD, south Delta exports, or NBA; also summarized were the percentage of particles remaining in Delta channels and the percentage of particles having past Martinez. The total number of particles released at each location was 4,000. Note that a 30-day particle tracking period may result in relatively low fate resolution at low flows (Kimmerer and Nobriga 2008), but the relative differences between scenarios would be expected to be consistent, based on previous model comparisons of 30-day and 60-day fates.

Table 6.A-7. Delta Smelt Mean Length in 20 mm Larval Survey for Each Survey Period by Survey Year (1995–2011)

Year	Month of Selected Survey[1]	Mean Fish Length (mm) for Each Survey Period[2]								
		Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Survey 6	Survey 7	Survey 8	Survey 9
1995	April	**13.3**	19.2	19.9	19.0	21.1	21.0	21.2	24.2	–
1996	May	8.6	11.2	**14.5**	17.6	17.8	21.7	22.8	23.3	–
1997	May	7.8	9.8	12.2	**13.5**	17.2	23.5	24.9	25.4	25.5
1998	May	11.0	10.0	15.3	**14.2**	17.1	21.6	26.0	24.4	27.5
1999	April/May	10.2	**12.0**	15.8	20.3	19.1	18.9	21.4	23.2	–
2000	May	5.9	9.8	11.2	**12.5**	15.1	19.8	20.1	22.6	–
2001	May	7.5	8.6	10.6	11.5	**14.8**	21.2	23.6	25.6	–
2002	April/May	0.0	8.0	11.1	**13.9**	19.1	23.1	23.3	23.2	–
2003	May	6.3	10.2	10.8	**13.6**	16.4	19.7	20.4	20.3	–
2004	May	10.9	9.1	10.5	**16.8**	20.9	21.7	24.0	27.8	–
2005	April	6.7	11.0	11.7	**14.0**	14.9	20.1	22.2	24.8	20.8
2006	May	0.0	0.0	10.9	0.0	**13.8**	18.0	18.9	21.5	21.4
2007	April	5.6	6.3	9.5	**13.7**	12.3	22.0	21.6	25.0	27.7
2008	April/May	0.0	0.0	11.6	**14.1**	17.0	22.4	22.1	26.8	28.7
2009	April	0.0	0.0	9.4	**13.2**	10.9	18.0	23.6	21.8	23.5
2010	April	6.3	0.0	11.9	**13.4**	13.1	19.3	18.5	18.8	21.3
2011	April	6.0	5.0	8.5	**12.5**	16.7	15.8	16.7	19.2	20.8

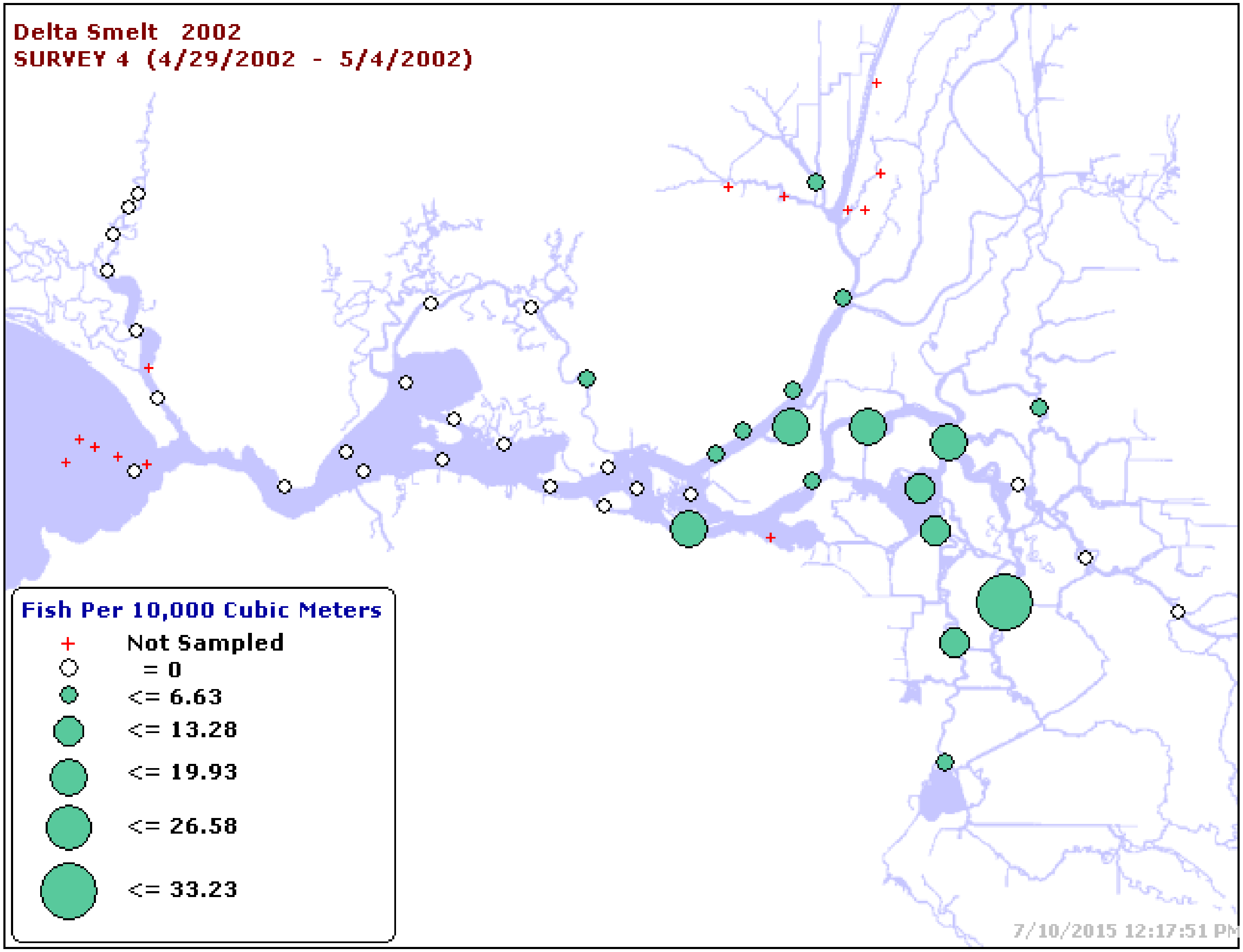
[1] Month of survey period with mean Delta Smelt length approximately 13 mm.

[2] Average length of Delta Smelt caught at all stations, by survey number. Survey chosen to provide starting distribution values are highlighted in **red bold** font.

Table 6.A-8. Distribution of Larval Delta Smelt (Number of Smelt) in Selected Survey Period (Survey Number)

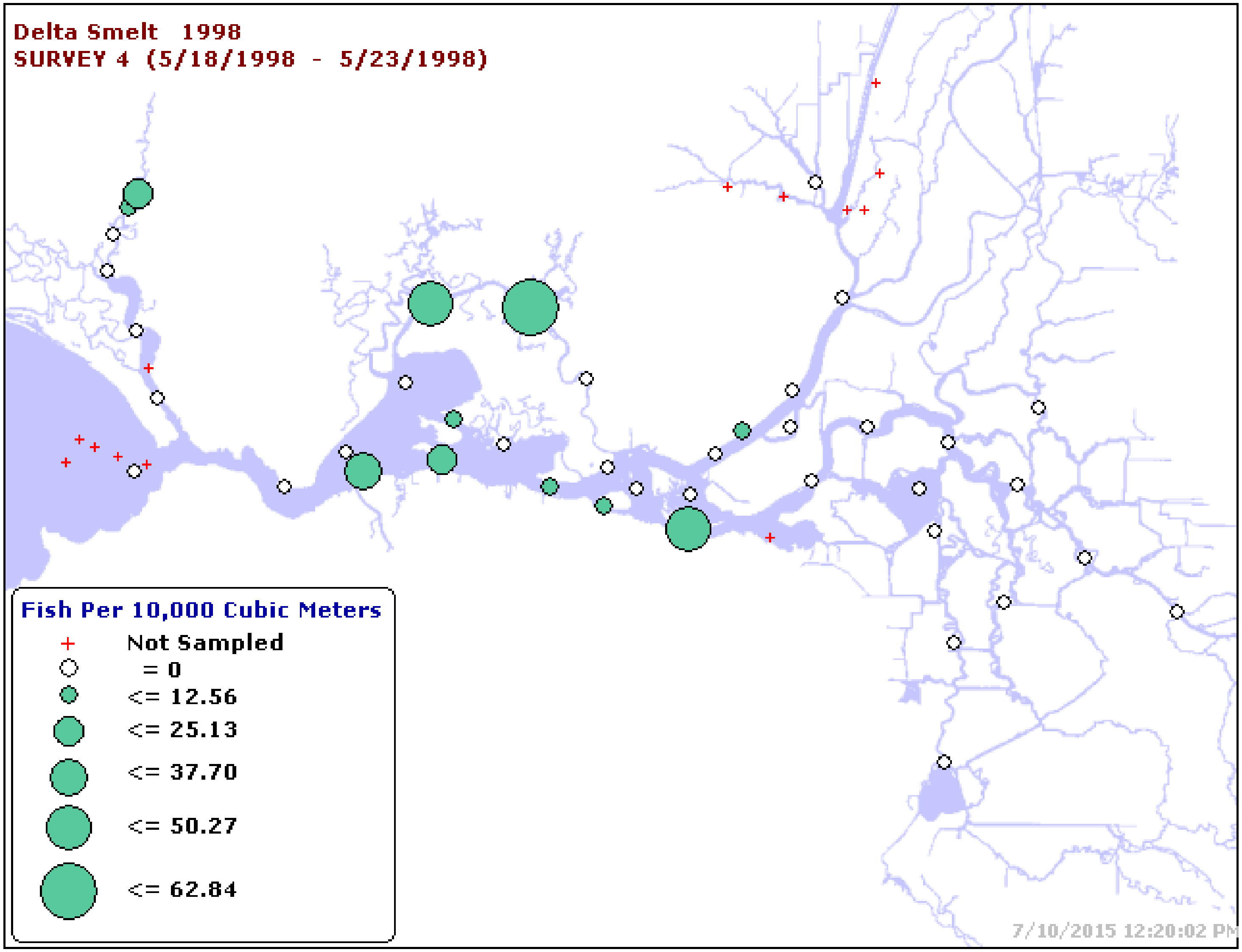
Year	Selected Survey Number[1]	Average Monthly Outflow (cfs)[2]	Delta Smelt Count by Sampling Stations																			Number of Delta Smelt Caught at Other Stations		Percentage of Total Count Not Considered for Starting Distribution	
			West Delta/ Sacramento–San Joaquin Confluence				West Delta/Lower Sacramento River				Cache Slough and North Delta			West Delta/Lower San Joaquin River					South Delta		East Delta				
			508	513	520	801	704	705	706	707	711	716	719	804	809	812	815	901	902–915	918	919	Cache Slough Stations	Downstream of Confluence	Cache Slough Stations	Downstream of Confluence
1995	1	90,837	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	7	0.0	63.6
1996	3	46,021	51	110	65	41	11	4	4	–	–	–	–	8	20	8	3	5	0	1	1	0	567	0.0	63.1
1997	4	12,257	–	3	26	2	8	12	14	–	7	6	–	32	13	6	5	5	4	–	5	0	66	0.0	30.8
1998	4	67,612	1	–	1	–	–	–	2	–	–	–	–	12	–	–	–	–	–	–	–	0	43	0.0	72.9
1999	2	35,509	3	1	–	8	4	–	–	–	–	–	–	15	–	–	18	7	45	–	–	0	127	0.0	55.7
2000	4	22,057	1	18	9	18	–	1	1	–	1	3	–	8	–	1	1	–	18	21	1	0	46	0.0	31.1
2001	5	9,612	–	1	–	–	3	14	5	11	1	5	–	–	28	49	13	13	11	1	10	0	8	0.0	4.6
2002	4	13,483	–	–	–	–	–	5	1	–	1	1	–	4	1	3	5	2	14	1	1	0	1	0.0	2.5
2003	4	41,877	1	1	1	2	–	1	–	–	–	2	–	4	1	–	–	1	8	–	–	0	7	0.0	24.1
2004	4	12,354	–	7	–	13	1	8	3	2	–	2	–	5	87	6	26	4	3	2	–	0	20	0.0	10.6
2005	4	29,876	2	7	2	1	–	–	1	–	–	1	–	–	–	–	1	–	2	1	–	0	50	0.0	73.5
2006	5	82,004	–	–	–	–	–	1	–	–	1	3	–	1	–	–	1	–	–	–	–	0	242	0.0	97.2
2007	4	11,235	–	–	–	–	–	–	1	–	1	–	–	–	–	–		–	–	–	–	0	1	0.0	33.3
2008	4	9,482	–	–	–	1	1	–	–	–	–	–	2	1	–	1	2	–	3	–	–	10	0	47.6	0.0
2009	4	11,944	–	–	–	–	–	1	–	–	–	1	12	–	–	–	1	–	2	–	–	4	1	18.2	4.5
2010	4	25,102	–	2	1	1	–	–	1	–	–	2	38	1	–	–	1	–	1	–	–	16	4	23.5	5.9
2011	4	84,981	–	–	1	–	–	–	–	–	–	1	39	–	–	–	–	–	–	–	–	4	120	2.4	72.7

[1] The first survey of the year when mean Delta Smelt length was closest to 13 mm.
[2] Average monthly Delta outflow calculated from observed vales in DAYFLOW. If the selected 5-day survey period occurred in two months, the predominant month was chosen for the mean flow.



Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: July 10, 2015.

Figure 6.A-8. Density of Delta Smelt from 20 mm Survey 4, 2002



Source: http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp. Accessed: July 10, 2015.

Figure 6.A-9.Density of Delta Smelt from 20 mm Survey 4, 1998

Table 6.A-9. Area of Water Represented by Each 20 mm Survey Station

Station	Area (acres)	Station	Area (acres)
508	2,296	812	1,767
513	1,703	815	4,023
520	438	901	3,822
801	2,226	902	1,744
704	605	906	1,780
705	277	910	1,925
706	931	912	1,225
707	1,859	914	1,554
711	1,994	915	1,146
716	3,110*	918	1,601
719	3,110*	919	2,043
804	1,195		
809	1,392		

Source: Saha 2008.
*Acreage for Station 716 was split between Stations 716 and 719.

Table 6.A-10. Percentage of Particles at PTM Insertion Location Used as Starting Distributions in the Delta Smelt Particle Tracking Analysis

Area	Average Monthly Outflow in cfs:	9,482	9,612	11,235	11,944	12,257	12,354	13,483	22,057	25,102	29,876	35,509	46,021	67,612	82,004	84,891	90,837
	Insertion Location	**Percentage of Particles**															
Sacramento –San Joaquin Confluence	Sacramento River at Sherman Lake	16.52	7.72	1.65	0	8.21	0	0.11	2.65	0	6.55	2.65	19.9	3.65	0	2.92	25.00
	Sacramento River at Port Chicago	16.52	7.72	1.65	0	8.21	0	0.11	2.65	0	6.55	2.65	19.9	3.65	0	2.92	25.00
	San Joaquin River downstream of Dutch Slough	16.52	7.72	1.65	0	8.21	0	0.11	2.65	0	6.55	2.65	19.9	3.65	0	2.92	25.00
	Sacramento River at Pittsburg	16.52	7.72	1.65	0	8.21	0	0.11	2.65	0	6.55	2.65	19.9	3.65	0	2.92	25.00
Lower Sacramento River	Threemile Slough	1.30	0.67	4.24	8.76	6.96	10.64	9.10	2.35	6.00	4.13	2.35	2.13	2.12	8.76	0	0
	Sacramento River at Rio Vista	1.30	0.67	4.24	8.76	6.96	10.64	9.10	2.35	6.00	4.13	2.35	2.13	2.12	8.76	0	0
	Sacramento River downstream of Decker Island	1.30	0.67	4.24	8.76	6.96	10.64	9.10	2.35	6.00	4.13	2.35	2.13	2.12	8.76	0	0
Cache Slough and North Delta	Miner Slough	0.32	0.35	0.06	5.86	1.26	1.05	0.40	0	9.11	0.60	0	0	0	5.86	9.82	0
	Sacramento Deep Water Ship Channel	0.32	0.35	0.06	5.86	1.26	1.05	0.40	0	9.11	0.60	0	0	0	5.86	9.82	0
	Cache Slough at Shag Slough	0.32	0.35	0.06	5.86	1.26	1.05	0.40	0	9.11	0.60	0	0	0	5.86	9.82	0
	Cache Slough at Liberty Island	0.32	0.35	0.06	5.86	1.26	1.05	0.40	0	9.11	0.60	0	0	0	5.86	9.82	0
	Lindsey Slough at Barker Slough	0.32	0.35	0.06	5.86	1.26	1.05	0.40	0	9.11	0.60	0	0	0	5.86	9.82	0
	Sacramento River at Sacramento	0.32	0.35	0.06	5.86	1.26	1.05	0.40	0	9.11	0.60	0	0	0	5.86	9.82	0
	Sacramento River at Sutter Slough	0.32	0.35	0.06	5.86	1.26	1.05	0.40	0	9.11	0.60	0	0	0	5.86	9.82	0
	Sacramento River at Ryde	0.32	0.35	0.06	5.86	1.26	1.05	0.40	0	9.11	0.60	0	0	0	5.86	9.82	0
	Sacramento River near Cache Slough confluence	0.32	0.35	0.06	5.86	1.26	1.05	0.40	0	9.11	0.60	0	0	0	5.86	9.82	0

	Average Monthly Outflow in cfs:	**9,482**	**9,612**	**11,235**	**11,944**	**12,257**	**12,354**	**13,483**	**22,057**	**25,102**	**29,876**	**35,509**	**46,021**	**67,612**	**82,004**	**84,891**	**90,837**
Area	**Insertion Location**	**Percentage of Particles**															
West Delta/ San Joaquin River	San Joaquin River at Potato Slough	0.80	2.86	25.12	7.00	10.87	11.13	19.73	17.80	0	13.16	17.80	4.24	26.34	7.00	0	0
	San Joaquin River at Twitchell Island	0.80	2.86	25.12	7.00	10.87	11.13	19.73	17.80	0	13.16	17.80	4.24	26.34	7.00	0	0
	San Joaquin River near Jersey Point	0.80	2.86	25.12	7.00	10.87	11.13	19.73	17.80	0	13.16	17.80	4.24	26.34	7.00	0	0
Central/ South Delta	San Joaquin River downstream of Rough and Ready Island	2.47	5.50	0.47	0	0.07	2.34	0.50	2.89	0	1.66	2.89	0.10	0	0	0	0
	San Joaquin River at Buckley Cove	2.47	5.50	0.47	0	0.07	2.34	0.50	2.89	0	1.66	2.89	0.10	0	0	0	0
	San Joaquin River near Medford Island	2.47	5.50	0.47	0	0.07	2.34	0.50	2.89	0	1.66	2.89	0.10	0	0	0	0
	Old River near Victoria Canal	2.47	5.50	0.47	0	0.07	2.34	0.50	2.89	0	1.66	2.89	0.10	0	0	0	0
	Old River at Railroad Cut	2.47	5.50	0.47	0	0.07	2.34	0.50	2.89	0	1.66	2.89	0.10	0	0	0	0
	Old River near Quimby Island	2.47	5.50	0.47	0	0.07	2.34	0.50	2.89	0	1.66	2.89	0.10	0	0	0	0
	Middle River at Victoria Canal	2.47	5.50	0.47	0	0.07	2.34	0.50	2.89	0	1.66	2.89	0.10	0	0	0	0
	Middle River u/s of Mildred Island	2.47	5.50	0.47	0	0.07	2.34	0.50	2.89	0	1.66	2.89	0.10	0	0	0	0
	Grant Line Canal	2.47	5.50	0.47	0	0.07	2.34	0.50	2.89	0	1.66	2.89	0.10	0	0	0	0
	Frank’s Tract East	2.47	5.50	0.47	0	0.07	2.34	0.50	2.89	0	1.66	2.89	0.10	0	0	0	0
East Delta	Little Potato Slough	0	0.08	0	0	0.26	0.30	0.74	0.00	0	0	0	0.03	0	0	0	0
	Mokelumne River downstream of Cosumnes confluence	0	0.08	0	0	0.26	0.30	0.74	0.00	0	0	0	0.03	0	0	0	0
	South Fork Mokelumne	0	0.08	0	0	0.26	0.30	0.74	0.00	0	0	0	0.03	0	0	0	0
	Mokelumne River downstream of Georgiana confluence	0	0.08	0	0	0.26	0.30	0.74	0.00	0	0	0	0.03	0	0	0	0
	North Fork Mokelumne	0	0.08	0	0	0.26	0.30	0.74	0	0	0	0	0.03	0	0	0	0
	Georgiana Slough	0	0.08	0	0	0.26	0.30	0.74	0	0	0	0	0.03	0	0	0	0

The 20 mm survey does not sample far enough upstream to inform the risk of entrainment at the proposed NDD, although Delta Smelt do occur in that reach based on other surveys (see discussion in Chapter 6, Section 6.1.3.2, *North Delta Exports*). As shown in Table 6.A-10, the single particle release location upstream of the NDD (Sacramento River at Sacramento) was included in the Cache Slough and north Delta grouping of release locations. Given that the density of Delta Smelt in the vicinity of and upstream of the NDD would be expected to be lower than the other stations in these release locations, but the particles were assumed to be equally distributed among these stations, this may generate an overestimate of the percentage of particles entrained by the NDD.

6.A.4 Habitat Effects

6.A.4.1 Abiotic Habitat Suitability (Feyrer et al. 2011)

Potential differences between PA and NAA in the extent of abiotic habitat for Delta Smelt in the fall (September–December, the older juvenile rearing and maturation period) as a function of changes in outflow (X2) were assessed using a technique based on the method of Feyrer et al. (2011).

Feyrer et al. (2011) demonstrated that X2 in the fall correlates nonlinearly with an index of Delta Smelt abiotic habitat (see Figure 3 of Feyrer et al. 2011). Note that the underlying data used in the analysis by Feyrer et al. (2011) did not include sampling stations in the Cache Slough area north of Rio Vista. As such, their model may have underestimated the frequency that Delta Smelt will use the turbid, very low-salinity water. Investigations in recent years have suggested that Delta Smelt occur year-round in the Cache Slough area, including Cache Slough, Liberty Island, and the Sacramento Deep Water Ship Channel; however, numbers have often been considerably lower in the warmer summer and fall months than during the cooler winter and spring months (Baxter et al. 2010; Sommer et al. 2011). The Delta Smelt fall abiotic habitat index is the surface area of water in the regions indicated by Figure 3 of Feyrer et al. (2011) weighted by the probability of presence of Delta Smelt based on water clarity (Secchi depth) and salinity (specific conductance) in the water. Feyrer et al.'s (2011) method found these two variables to be significant predictors of Delta Smelt presence in the fall and also concluded that water temperature was not a meaningful predictor of Delta Smelt presence in the fall, although it has been shown to be important during summer months when water temperatures are higher (Nobriga et al. 2008).

The low salinity zone, the extent of which correlates positively with X2 and therefore with the abiotic habitat index of Feyrer et al. (2011), largely overlaps the distribution of other essential physical resources and key biotic resources that are necessary to support Delta Smelt but that are not explicitly represented in the abiotic habitat index, and the higher the outflow, the more habitat and habitat variability there is for Delta Smelt to exploit. The abiotic habitat index is based on the probability of presence of Delta Smelt given certain water clarity and salinity and does not explicitly account for other abiotic (e.g., water velocity, depth) and biotic (e.g., food density) factors that may interact with water clarity and salinity to influence the probability of occurrence. However, Delta outflow and its effects on X2 are habitat elements that the projects can directly influence, whereas the other habitat features are not.

Various peer-reviewed studies have statistically examined linkages between fall abiotic habitat (often indexed by X2) and indices of Delta Smelt abundance or survival. Feyrer et al. (2007) found that Delta Smelt abundance in summer was positively related to prior fall abundance, and negatively related to prior fall salinity and water clarity. Mac Nally et al. (2010) found no evidence for a relationship between fall X2 and Delta Smelt fall abundance. Miller et al. (2012) found that neither fall X2 nor the volume of suitable fall habitat (with suitability based on salinity, water clarity, and temperature) were able to explain additional variability in trends in Delta Smelt fall-to-fall survival, beyond direct factors included in a best regression model.

As previously noted in the description of analyses related to south Delta entrainment, the CAMT has the mission of working to develop a robust science and adaptive management program through the CSAMP that will inform both the implementation of the current BiOps and the development of revised BiOps. This adaptive management team has formulated a workplan that identifies a number of key questions and possible investigative approaches to the issue of fall outflow management (Table 6.A-11; Collaborative Adaptive Management Team 2014); the investigations resulting from this work would directly inform fall outflow management under both the NAA and the PA. Such work is important to address scientific uncertainty and debate regarding the importance of fall abiotic habitat for Delta Smelt, and the methods used to analyze it. Regarding the Feyrer et al. (2011) method, the overall relationship between X2 and the Delta Smelt fall abiotic habitat index is the result of two linked statistical analyses, each of which has uncertainty that is compounded when the analyses are combined. The National Research Council (2010) has expressed concern about the effects of compounding uncertainty in linked statistical analyses such as Feyrer et al.'s (2011) analysis and its implication for quantitative conclusions. Additionally, they noted that the "weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action [the prescribed locations for X2 in the Delta in wet and above-normal years] difficult to understand. In addition, although the position of X2 is correlated with the distribution of salinity and turbidity regimes (Feyrer et al. 2007), the relationship of that distribution and smelt abundance indices is unclear" (National Research Council 2010: 5).

Table 6.A-11. Key Questions and Possible Investigative Approaches to Address Fall Outflow Management as Part of the Collaborative Adaptive Management Team Fall Outflow Workplan

Key Questions	Possible Investigative Approaches
Are there biases in the IEP survey data? How should the survey data be utilized if biases do exist?	Convene a workshop to discuss possible survey problems and identify opportunities to address in 2014 with existing data. Consider ongoing work and approaches of Emilio Laca. Many of these issues have been proposed by FWS to be addressed through a package of gear efficiency and smelt distribution studies; however, that package includes extensive field work, and some elements have timelines extending beyond the remand period.
Under what circumstances does survival in the fall affect subsequent winter abundance?	Quantitatively determine the contribution of Delta Smelt survivorship in the fall to inter-annual population variability. Review available lifecycle models for applicability.
Under what circumstances do environmental conditions in the fall season contribute to determining the subsequent abundance of Delta Smelt?	Investigate the relationship between fall outflow and the relative change in Delta Smelt abundance using univariate and multivariate and available historic data. Related to work undertaken in the Management, Analysis, and Synthesis Team (MAST) report, which examined pairs of dry and wet years in 2005/6 and 2010/11. Also explore effects occurring through other avenues (e.g. growth or fecundity).
How much variability in tidal, daily, weekly, and monthly fluctuations in fall X2 is attributable to water project operations?	Hydrological modeling tools to determine the prospective locations of X2 in the fall under circumstances with and without project operations. An analysis of historical data will also be carried out to examine outflow during periods when the projects were required to meet specific outflow requirements, to evaluate the degree of control that has been possible at various time scales. See work addressing this issue by: Grossinger, Hutton, and a paper by Cloern and Jassby (2012)
Under what circumstances is survival of Delta Smelt through the fall related to survival or growth rates in previous life stages?	Compare Delta Smelt survival during the fall to both survival in prior seasons and to fork length at the end of the summer/start of the fall. New data are being collected as part of the Fall Outflow Adaptive Management Plan (FOAMP). Consider individual-based modeling (IBM).
Does outflow during the fall have significant effects on habitat attributes that may limit the survival and growth of Delta Smelt during the fall?	There may be competing approaches that will be simultaneously pursued. One is to develop graphs and conduct univariate and multivariate analyses involving survival ratios and growth rates. Test whether month-to-month declines in abundance or growth during the fall is greater when X2 is located further east. See also the analytical approach in MAST report, work by Kimmerer, Burnham & Manly.
Can an index based on multiple habitat attributes provide a better surrogate for Delta Smelt habitat than one based only on salinity and turbidity?	Review approaches in existing literature. There may be competing approaches that will be simultaneously pursued, depending on expert advice. One possible approach is to develop suitability index curves and combine geometrically to create a habitat quality index. Utilize data from areas where Delta Smelt are frequently observed to assess habitat quality. See work by Burnham, Manly, and Guay.
Under what conditions (e.g., distribution of the population, prey density, contaminants) do fall operations have significant effects on survival?	Utilizing relationships identified in the above studies, simulate how changes in project operations may influence survival of Delta Smelt during the fall.
Source: Collaborative Adaptive Management Team (2014)	

6.A.4.1.1.1 Development of the Original X2–Fall Abiotic Habitat Index

The methods for developing the abiotic habitat index and its relationship to X2 are described in more detail by Feyrer et al. (2011). The description below is adapted from their account.

FMWT survey data were used to develop the index. The FMWT samples approximately 100 stations across the estuary each month from September to December (Stevens and Miller 1983). A subset of 73 of the 100 stations was used for analyses to avoid including stations where sampling had not occurred consistently or where Delta Smelt were rare. Each station was sampled once per month, each of the four months, from 1967 to 2008 with a single 10-minute tow. The only exceptions were that sampling was not conducted in 1974 and 1979, and in 1976 was conducted only in October and November. Measurements of the water quality variables normally are taken coincident with each sample. In total, there were nearly 14,000 individual samples with complete data for analysis spanning 42 years.

Generalized additive modeling (GAM) was used to estimate the probability of occurrence of Delta Smelt at a trawl station in a given month and year based on water temperature (°C), water clarity (Secchi depth, meters), and specific conductance, a surrogate for salinity (microSiemens per centimeter [µs/cm]). The probability of occurrence (i.e., presence-absence data) was used as the dependent variable rather than a measure of abundance (e.g., catch per trawl) to minimize the possible influence of outliers and bias associated with long-term abundance declines. This approach is supported by recent simulations, based on assumed underlying statistical distributions of fish catch, that suggest habitat curves based on presence-absence are conservative relative to catch per trawl because high frequencies of occurrence could be associated with both high and moderate catch per trawl (Kimmerer et al. 2009).

Model fits were evaluated in terms of the reduction in deviance (a measure of the explanatory power of the model, similar to variance in other modeling techniques such as analysis of variance) attributable to each of the abiotic factors, relative to a null model. The final model included Secchi depth and specific conductance but did not include water temperature, as it did not give an appreciable reduction in deviance or suggest a pattern consistent with a priori expectations. The final model accounted for 26% of the deviance. There are a number of reasons why the deviance reduction is this low, including species decline that affects the probability of catching a fish, zooplankton declines, and insufficient habitat parameters available in the FMWT data set. Of these, zooplankton decline may be particularly important (Miller et al. 2012; Rose et al. 2013a, 2013b). Nonetheless, the model is able to quantify how the basic extent of usable habitat has varied through time. These concepts were recognized prior to the analyses done by Feyrer et al. (2007, 2011), Nobriga et al. (2008), and Kimmerer et al. (2009), but they have been described in more qualitative ways (Moyle et al. 1992; Bennett 2005) or with a focus on striped bass (Turner and Chadwick 1972) or the low-salinity zone ecosystem (Jassby et al. 1995).

The Delta Smelt fall abiotic habitat index was calculated as follows:

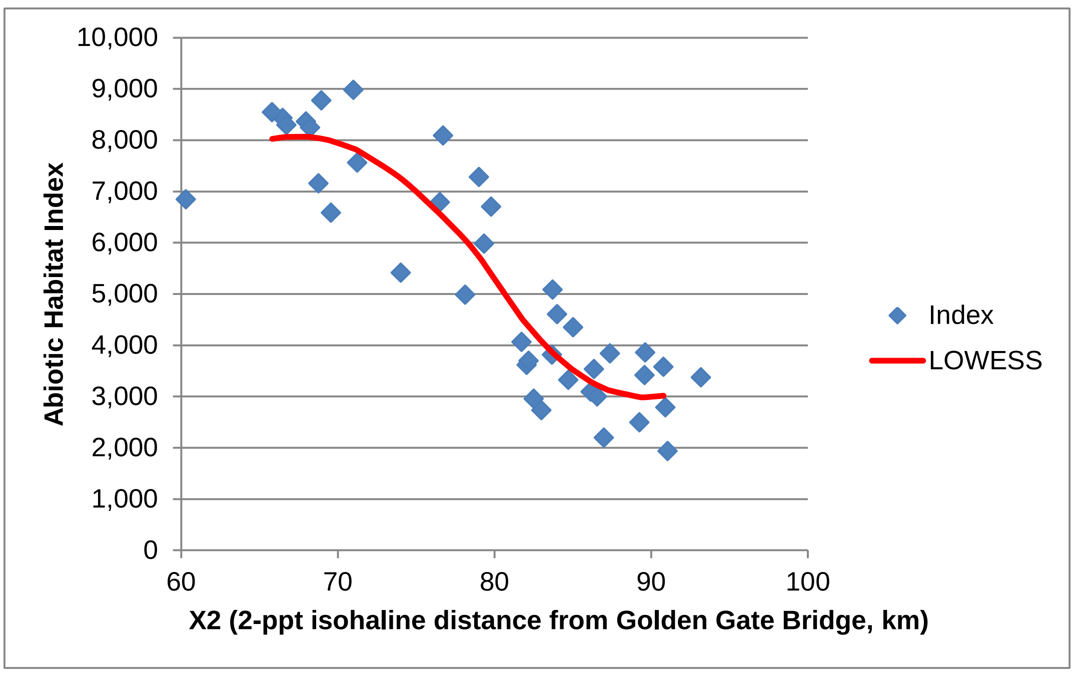
$$H_y = \sum_{S=1}^{73}\left[A_s \frac{1}{4}\sum_{m=Sep}^{Dec}\hat{\pi}_{y,m,s}\right]$$

(Equation 1)

Where H_y is the fall abiotic habitat index, A_s is the surface area of station s and $\hat{\pi}_{y,m,s}$ is the GAM estimate of the probability of occurrence.

Station surface areas of each station were obtained from CDFW and originally were reported by Feyrer et al. (2007). CDFW generated surface area estimates using GIS that ranged from 90 to 1,251 hectares per station for the 73 stations. Summation of the probability of occurrence–weighted surface areas provided an index that accounts for both the quantity and value (in terms of probability of occurrence) of abiotic habitat for Delta Smelt.

Feyrer et al.’s (2011) annual values of the Delta Smelt fall abiotic habitat index predicted from the influence of observed Secchi depth and conductivity data on Delta Smelt detections, as well as the relationship of those predictions to mean September through December X2, are represented by the blue diamonds in Figure 6.A-10. Feyrer et al. (2011) used locally weighted regression–scatterplot smoothing (LOWESS regression) to develop a data-driven relationship between the habitat index and mean September to December X2 (red line in Figure 6.A-10). The LOWESS smoothed fit suggests that variation in X2 explained 85% of the variation in the estimates of abiotic habitat (i.e., $r^2 = 0.85$). The data were averaged over the 4-month fall period to minimize the influence of sampling error that could occur if the data were summarized over shorter temporal scales. For instance, shorter averaging periods might be less reliable because samples are taken irrespective of tidal conditions across a geographic region with large tidal excursions, and because abundance estimates, and by extension distribution, can be highly variable among months (Newman 2008).



Source: Feyrer (pers. comm.)

Figure 6.A-10. Abiotic Habitat Index of Delta Smelt in Relation to X2

6.A.4.1.1.2 Use of the Delta Smelt Fall Abiotic Habitat Index in the Effects Analysis

The fitted values underlying the relationship of Delta Smelt fall abiotic habitat index to X2 (red line in Figure 6.A-10) were used to estimate fall abiotic habitat under the NAA and PA scenarios. The X2-abiotic habitat index relationship estimates the habitat index to decrease with X2 downstream of approximately 67 kilometers (km) and to increase with X2 upstream of approximately 90 km. For this analysis, it was assumed that there would be little change in habitat index with X2 lower than approximately 67 km and greater than approximately 90 km. Therefore, X2 less than approximately 67 km was assumed to have the maximum index of approximately 8,068, whereas X2 greater than approximately 90 km was assumed to have the minimum index of approximately 2,985. For each year of the CALSIM period (water years 1922–2002[3]), the mean X2 was calculated for September through December and the abiotic habitat index for the NAA and PA scenarios was estimated by linear interpolation of the values shown in Table 6.A-12.

Table 6.A-12. Fitted Values for Delta Smelt Abiotic Habitat Index

X2 (km)	Abiotic Habitat Index	X2 (km)	Abiotic Habitat Index
67.965	8,067.8	82.183	4,365.9
68.237	8,061.2	82.515	4,248.7
68.775	8,039.5	83.000	4,080.6
68.953	8,029.9	83.680	3,866.2
69.573	7,987.2	83.715	3,856.2
71.000	7,837.2	84.000	3,776.9
71.255	7,802.8	84.710	3,592.1
74.022	7,255.3	85.028	3,516.2
76.513	6,562.9	86.160	3,286.1
76.720	6,499.8	86.365	3,252.1
78.127	6,058.6	86.555	3,222.6
79.022	5,725.8	87.000	3,160.2
79.353	5,584.8	87.373	3,115.0
79.787	5,389.8	89.263	2,988.7
81.737	4,527.7	89.590	2,984.8
82.070	4,405.3	89.625	2,984.7
Source: Feyrer (pers. comm.)			

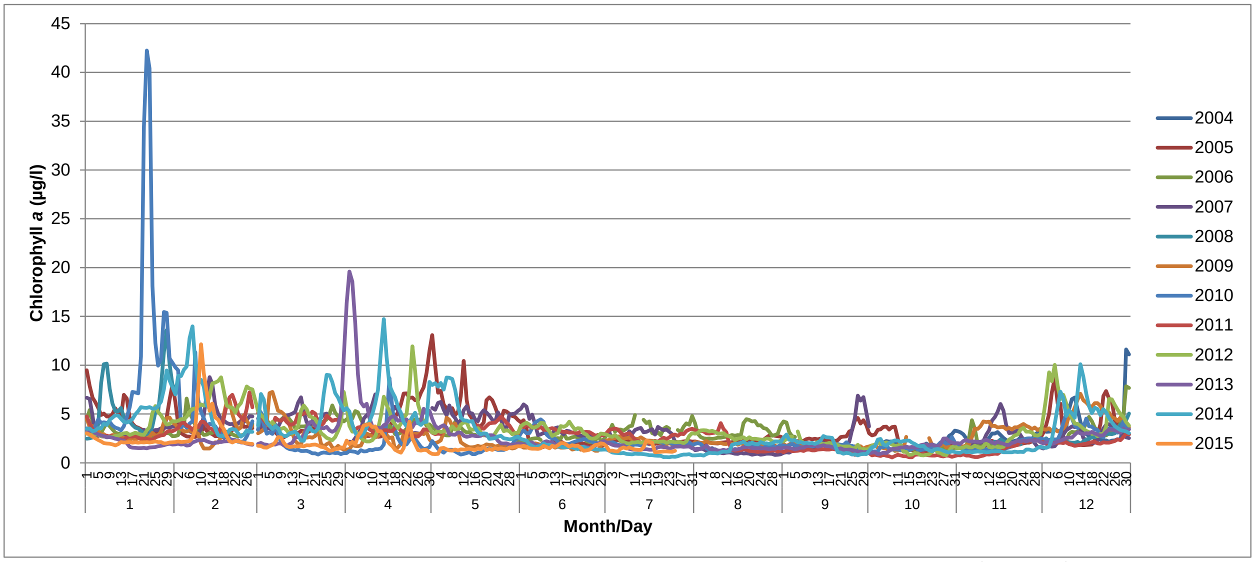
6.A.4.2 Food Web Material Entrainment by the NDD

As described in Chapter 6, *Effects Analysis for Delta Smelt and Terrestrial Species,* by removing water from the Sacramento River, the NDD will also remove small planktonic organisms that otherwise would enter the Delta where they could contribute to the food web that supports Delta Smelt. This section describes the methods used to estimate this loss in relation to the overall quantity of these organisms in the Delta, with the results being reported in Chapter 6.

The indicator of food web material entrainment used in this BA was phytoplankton carbon. This choice was based on data availability and the likelihood that phytoplankton cells would be

[3] Water year 2003 was omitted because only September data were available.

relatively uniformly distributed in the water column so that their removal from the river could be reasonably represented using DSM2-HYDRO outputs. Fluorescence data from a continuous recorder operated by DWR were assembled for various stations in the Delta. These data are calibrated to represent the concentration (µg/l) of chlorophyll *a* in the water column. Data from the Sacramento River at the town of Hood were used to estimate the rate of removal of phytoplankton carbon that otherwise would continue to be transported farther into the Delta. The 15-minute data were available from October 4, 2004, to July 27, 2015; daily means were calculated to simplify subsequent calculations (Figure 6.A-11).



Source: Gardner Jones, DWR (personal communication). Note: Chlorophyll *a* values are estimated by calibration from raw fluorescence data.

Figure 6.A-11. Daily Mean Chlorophyll *a* in the Sacramento River at Hood

The estimated chlorophyll *a* concentrations (µg/l) were converted to phytoplankton carbon using a standard ratio of 35 (Cloern et al. 1995, as cited by Jassby et al. 2002). Thus, there were 11 to 12 estimates of daily mean phytoplankton carbon concentrations for each calendar day of the year. The 11 to 12 estimates of mean phytoplankton carbon data were matched by day of the year to daily mean DSM2-HYDRO flow data for 1922–2003 to illustrate potential variability in NDD phytoplankton carbon entrainment across years. Sacramento River flow into the Delta (cubic feet per second, converted to metric units) was represented by RSAC155 (Freeport), and flow below the NDD was represented by 418_MID; RSAC155 minus 418_MID represented NDD export rate. Daily load (metric tons/day) of phytoplankton carbon entrained by the NDD was estimated for each day of the 1922–2003 DSM2-HYDRO simulation by multiplying NDD export flow by the corresponding daily mean concentration of phytoplankton carbon for 2004–2015. The resulting matrix of entrained phytoplankton carbon load (metric tons/day) was summarized into percentiles by month.

The estimates of phytoplankton carbon load entrained by the NDD were placed into the context of first-order estimates of the total biomass of phytoplankton carbon simultaneously present in the Delta by multiplying an estimated mean concentration of phytoplankton carbon in the Delta by a static average volume of the Delta (i.e., it was considered too speculative to try to adjust the volume of the Delta based on tidal cycles and flow variation). Fluorescence data—for Antioch from September 25, 2004, to July 27, 2015, were again converted to density of chlorophyll using the method described above for Hood. The Antioch data were assumed to provide a conservatively low chlorophyll *a* density compared to other available locations because of its proximity to areas that are intensively grazed by the overbite clam, so that the actual proportional entrainment is likely less than predicted using this method. The volume of the Delta upstream of Chipps Island— minus the Sacramento River upstream of Sutter Slough, in order to exclude the area approximately including and upstream of the NDD—is approximately 690,000 acre-feet, based on the Delta channel volumes that are used in the DSM2 model (see Table 5.2-1 in Section 5.2 of Jones & Stokes 2005). The total Delta-wide phytoplankton carbon biomass was estimated for each month of each year (2004 to 2015). From these data, the 5^{th}, 50^{th} (median), and 95^{th} percentiles of the NDD entrained phytoplankton carbon estimates were calculated to characterize the variability in the data. Note that this method does not account for in-situ production that would replace some portion of the entrained phytoplankton, as well as less entrainment by the south Delta export facilities under the PA; these factors are discussed qualitatively in Chapter 6.

6.A.4.3 *Microcystis* (DSM2-PTM Residence Time)

As described in Chapter 6, *Effects Analysis for Delta Smelt and Terrestrial Species*, water residence time is likely to be an important factor affecting the maintenance of *Microcystis* blooms in the Delta. This section describes the methods of a residence time analysis based on DSM2-PTM. The biological context for these results is discussed in Chapter 6. Further information regarding the methods are provided in Appendix 5.B, Section 5.B.3.5, *DSM2-PTM for Evaluating Delta Residence Times*. As described in Chapter 6, *Microcystis* blooms are likely driven by other factors that are not included in this analysis. Note that an analysis based on flow (Lehman et al. 2013), as opposed to residence time, is also included in Chapter 6.

It was necessary to choose a subset of years for the analysis of residence time because it was not feasible to conduct the analyses for the full 82-year time series (1922–2003) that had been simulated with DSM2-HYDRO. To this end, the mean July to November Delta exports, outflow, and inflow across all 82 years were computed for the NAA scenario. The 82 years were sorted into five export bins, and several years were selected within each bin after examining plots of inflow versus outflow to represent the range of flow conditions. A total of 25 years was chosen, and the DSM2-PTM simulations that were run were based on the DSM2-HYDRO simulations for these years.

For each of the 25 years included in the analysis, 90-day DSM2-PTM runs were undertaken beginning the first day in each month, from July to November. There were a total of 125 runs for both scenarios (NAA and PA) (i.e., 25 years × 5 months). Particles were inserted at locations that were grouped based on subregions used in the Delta Smelt Life Cycle Model (Newman et al. in prep.) (Figure 6.A-12 and Figure 6.A-13; Table 6.A-13). Four thousand particles were inserted per subregion, and were evenly divided between the insertion locations within each subregion. The predicted particle fates were used to estimate residence time under each of these 125 sets of conditions.

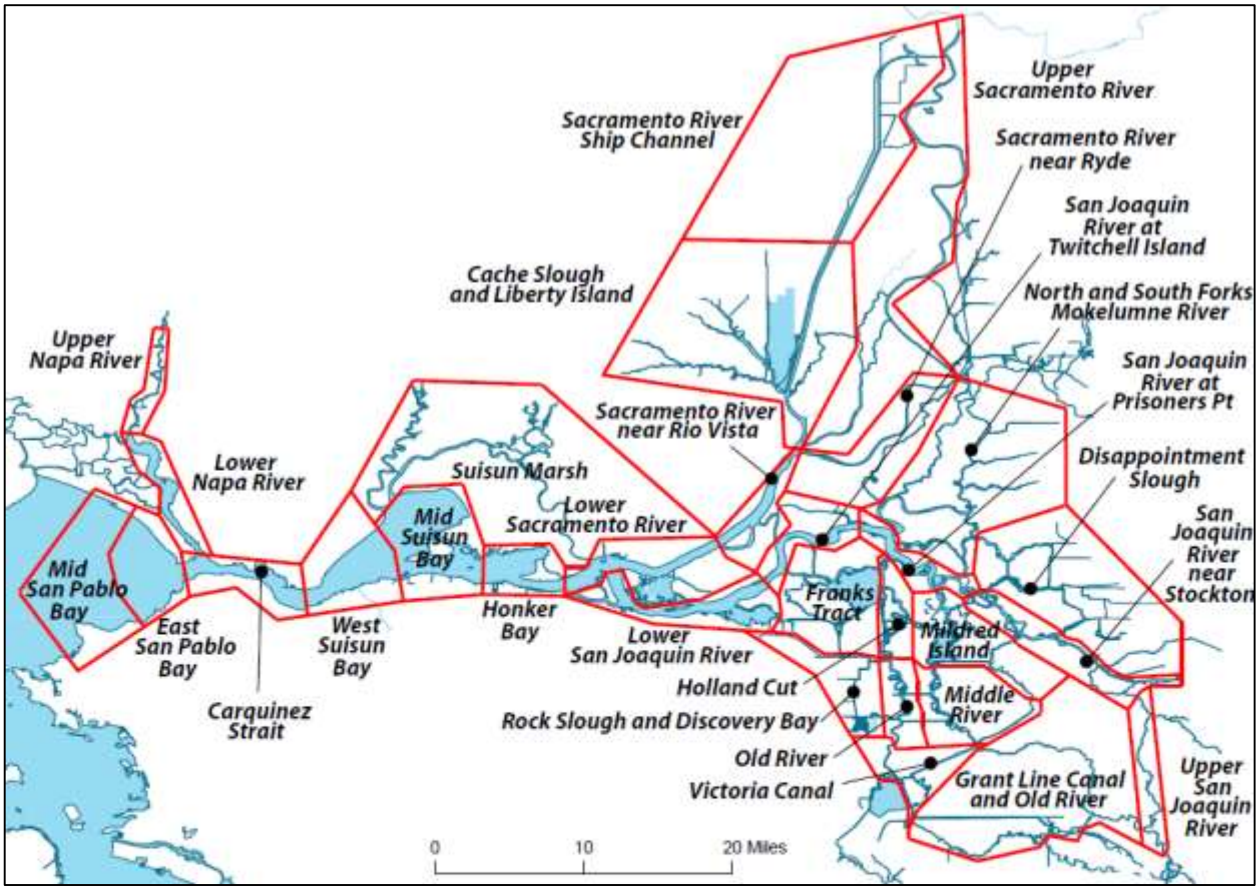


Figure 6.A-12. Subregions Used in the Analysis of Residence Time Based on DSM2-PTM

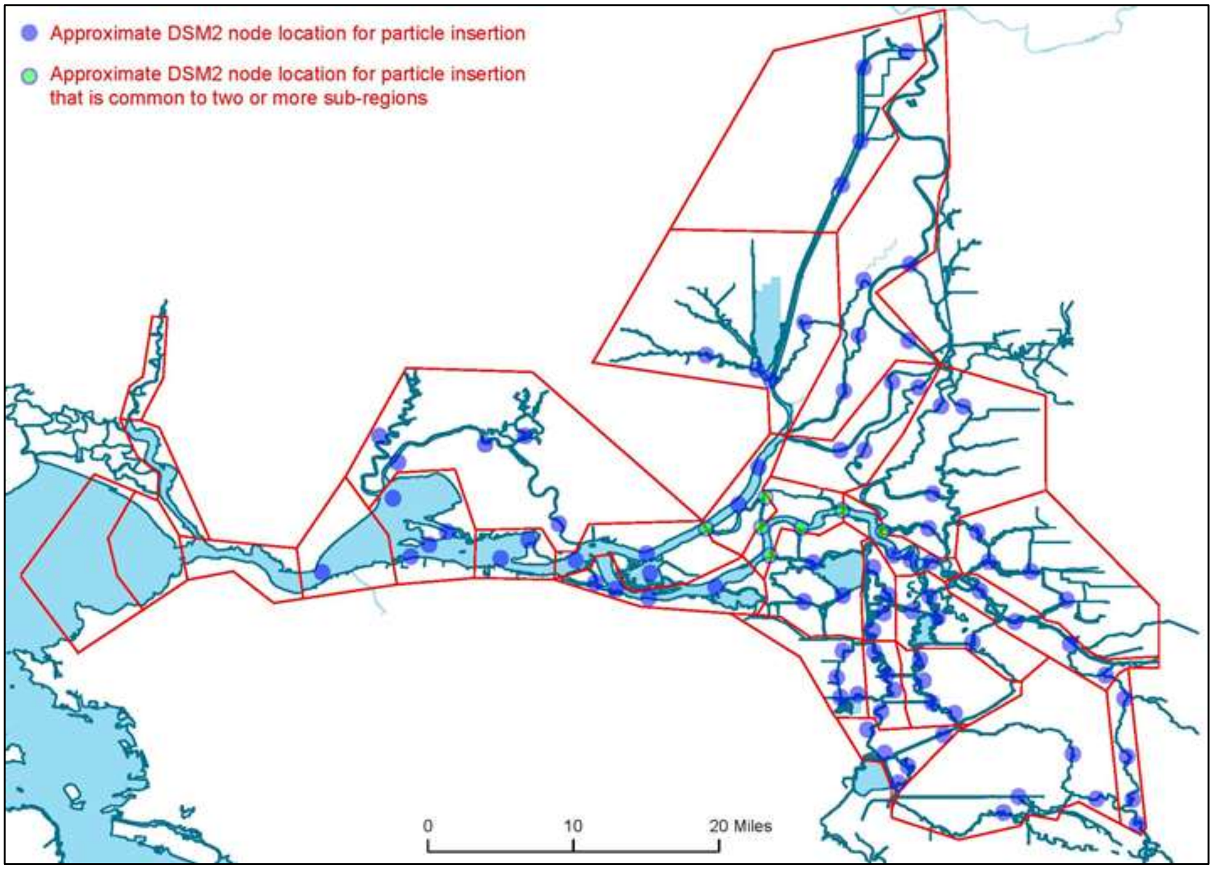


Figure 6.A-13. Particle Insertion Locations within the Subregions Used in the Analysis of Residence Time Based on DSM2-PTM

Table 6.A-13. DSM2-PTM Insertion Locations (Nodes) within the Subregions Used in the Analysis of Residence Time Based on DSM2-PTM.

Subregion	DSM2 Particle Insertion Nodes
Upper Sacramento River	338, 341, 300, 303, 305
Sacramento River Ship channel	309, 310, 311, 312
Cache Slough and Liberty Island	307, 316, 322, 325
Sacramento River near Ryde	344, 288, 348, 293
North and South Forks Mokelumne River*	281, 261, 269, 251, 39
Sacramento River near Rio Vista*	351, 352, 240, 43, 353
Lower Sacramento River*	353, 354, 459, 465
Upper San Joaquin River	7, 9, 11, 13
Grant Line Canal and Old River	50, 106, 171, 60
Victoria Canal	188, 185, 72, 79, 75
Rock Slough and Discovery Bay	197, 198, 200, 202
Old River	81, 84, 86, 92
Middle River	115, 117, 120, 124
Mildred Island	142, 130, 207, 133
San Joaquin River near Stockton	16, 22, 25, 30
Disappointment Slough	241, 242, 243, 248
San Joaquin River at Prisoners Pt*	34, 35, 37, 39, 41
Holland Cut	94, 98, 100, 101
Franks Tract*	225, 216, 222, 42, 44
San Joaquin River at Twitchell Island*	41, 42, 43, 44, 240
Lower San Joaquin River	45, 46, 47, 463
Honker Bay	357, 328
Suisun Marsh	406, 418, 422, 375, 428
Mid Suisun Bay	238, 329, 358, 365
West Suisun Bay	360

Note:
* Subregions that share DSM2 particle insertion nodes with one or more sub-regions.

The number of particles in the subregion was outputted from the PTM every hour over the 90-day simulation periods. Residence time (in hours) was calculated as the time since the start of the simulation *i* weighted by the number of particles remaining in the subregion at time *i*:

$$Residence\ time\ (hours) = \frac{\sum_{i=1}^{90*24}(No.of\ particles\ in\ the\ subregion)_i * i}{\sum_{i=1}^{90*24}(No.of\ particles\ in\ the\ subregion)_i}$$

Residence time in hours was converted to residence time in days for reporting purposes. The results are presented in tabular format in Chapter 6, *Effects Analysis for Delta Smelt and Terrestrial Species* by subregion and based on the 5th, 25th, 50th (median), 75th, and 95th

percentiles of the 25 simulated years for each month for the NAA and PA scenarios, with differences and percentage differences between scenarios for each percentile.

6.A.5 References

6.A.5.1 Printed References

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Appendix 6.B, Terrestrial Effects Analysis Methods

6.B Terrestrial Effects Analysis Methods

6.B.1 Introduction

This appendix describes the methods used to analyze the effects of the proposed action (PA) on federally listed species in the action area. In most cases, effects are evaluated by comparing the value of affected habitat to the value of habitat provided by offsetting measures. As required by the federal Endangered Species Act (ESA), the effects analysis also describes the level of take and the effect of that take on each covered species expected from implementation of the PA.

6.B.2 Spatial Extent of the Terrestrial Effects Analysis

The effects analysis for listed wildlife is primarily confined to the legal Delta (see Chapter 4, *Action Area and Environmental Baseline*, Figure 4-1 for the boundaries of the legal Delta). Nearby areas considered, which fall outside the legal Delta, include an area of transmission line construction that extends east beyond the legal Delta boundary. In addition, vernal pool restoration may occur west and south of Clifton Court Forebay, near but outside the bounds of the legal Delta; and giant garter snake conservation may occur east of the legal Delta or in the Yolo Bypass.

6.B.3 Temporal Extent of the Terrestrial Effects Analysis

Construction of the water conveyance facility will last for 14 years; activities included in the PA also include start-up of the new facilities (assumed to be 1 year) and tracking of operations and maintenance of all covered facilities for another 10 years. Thus, the temporal extent of the analysis is 25 years. Construction of all habitat restoration is expected to have been completed by construction completion. Monitoring and maintenance of restored and protected habitat will continue in perpetuity.

6.B.4 Methods for Assessment of Effects on Terrestrial Species

6.B.4.1 Incidental Take Assessment

The PA is expected to cause incidental take of covered species. To meet regulatory requirements and to ensure adequate mitigation of effects, the amount of take must be discussed and, if possible, quantified. The allowable amount of take is quantified by estimating the loss of habitat for each covered species, using estimation methods described below.

A list of activities entailed in the PA, their effects, and corresponding conservation measures to offset the effects are summarized in Table 6.B-2 and Table 6.B-3 below. Many of the proposed activities will avoid impacts to species habitat. Avoidance commitments are summarized by activity type in Table 6.B-4 and Table 6.B-5; impact assessments were not developed for those activities that will fully avoid affecting covered species.

The effects of construction of the water conveyance facilities can be assessed on the basis of a known disturbance footprint. The disturbance footprint used in the analysis has been determined to be the maximum footprint that will be needed; e.g., it includes all staging, storage and stockpile areas, etc. It is expected that actual impacts will affect a smaller footprint. The project proponent will track actual effects during implementation to demonstrate that effects do not exceed authorize levels, and offsetting measures will be implemented to compensate for actual impacts, as determined during final design and construction.

Restoration will be sited as described in Section 3.4.7, *Terrestrial Species Conservation*, and siting is subject to review and approval by USFWS staff during project implementation. The siting of some of the conservation measures is not precisely known, but the region where restoration is likely to occur is relatively well defined (e.g., vernal pool restoration in the Bryon Hills region). Because restoration has not yet been sited, assumptions were developed to conservatively estimate the maximum loss of species habitat potentially resulting from the conservation measures (Section 3.4.7, *Terrestrial Species Conservation*), as summarized in Table 6.B-3 below.

The estimates of suitable habitat loss presented in Section 5.7, *Effects Analysis for Delta Smelt and Terrestrial Species*, represent the maximum limit on total loss for which the project proponents are seeking incidental take authorization. Once those limits are reached, any request for further take authorization due to habitat loss will first require reinitiation of consultation.

6.B.4.2 Terrestrial Species Habitat Models

Habitat models bring together information about environmental attributes, species life history, and environmental requirements to create a spatially explicit model of suitable habitat at a regional scale. Habitat models collect a variety of information relating to habitat requirements to create hypotheses of species-habitat relationships rather than statements of proven cause and effect relationships (Schamberger et al. 1982). Habitat models for terrestrial species are formulated primarily using vegetation data from existing GIS data sources as described in BDCP Appendix 4.A, *Covered Species Accounts*, Section 4.A.0.1.7, *Species Habitat Suitability Model Methods* (California Department of Water Resources 2013).

The habitat models were created using existing GIS data that in some cases does not provide the necessary information to precisely identify suitable habitat characteristics for a species. For example, the riparian plant alliance data is not a good predictor of the structural characteristics necessary to support nesting least Bell's vireos or western yellow-billed cuckoos. For this reason, *modeled habitat* is differentiated from *suitable habitat*, as defined for each species in Appendix 4.A, *Covered Species Accounts.* Suitable habitat will be identified prior to ground breaking to refine the existing habitat mapping, identify appropriate avoidance and minimization measures, and ensure that effects do not exceed those analyzed in this BA.

6.B.4.3 Analysis of Adverse Effects

Potential adverse effects on each species were assessed in each of four categories:

- Permanent and temporary habitat loss, conversion, and fragmentation;
- construction-related effects; and
- effects of operation and maintenance.

Adverse effects from each of these categories were then assessed collectively in the context of species survival and conservation to determine the net effect on the species. For each effect category, effects were assessed collectively for the PA and for conveyance facility construction. For restoration activities, only those activities with the greatest level of effects in each effect category were assessed in detail. Each of the effects categories applied in the adverse effects analysis is described below along with the methods used to quantify impacts.

6.B.4.3.1 Habitat Loss, Conversion, and Fragmentation

Both permanent and temporary habitat loss and conversion[1] are expected to occur, both as a result of activities with known locations, and from activities with flexible locations. The quality of modeled species habitat was based on the potential for that habitat to support and sustain the species. Factors considered in assessing habitat quality included habitat patch size and isolation from other habitat; adjacent land uses such as roads and other development inferred from aerial imagery; proximity to existing protected lands; and other available information from literature, occurrence databases, and species experts related to species distribution relative to the habitat lost. For most of the covered species, species occurrence data are incomplete and therefore have limited utility for assessing the extent to which modeled habitat is occupied or determining the value of the habitat in terms of supporting populations of a species. However, DWR has conducted extensive field surveys in and around the conveyance facility footprint and alternative alignments for this facility, as detailed in Appendix 4.A, *Status of the Species and Critical Habitat Accounts*. Therefore, occurrence data are used to assess the value of habitat lost from conveyance facility construction more than they are used to assess the value of habitat lost from other activities under the PA.

The analysis of habitat fragmentation effects involved an evaluation of habitat surrounding the habitat to be lost, to determine whether the loss or conversion of habitat would create movement barriers or would isolate patches of remaining habitat in the area.

Activities with known locations include all proposed conveyance construction activities except geotechnical exploration, safe haven work areas, barge landings, and new electrical transmission lines; it also includes operations and maintenance of all existing and proposed CVP/SWP facilities except habitat restoration sites. Habitat loss resulting from activities with known locations was assessed by overlaying GIS data layers representing the geographic footprints of the ground disturbance areas for these activities with GIS data layers showing species habitat models.

Activities with flexible locations include transmission lines, geotechnical activities, safe haven interventions, barge landings, and the establishment and maintenance of habitat restoration sites. The methods applied to assess habitat loss for each of these activity types are described below.

6.B.4.3.1.1 Geotechnical Exploration

Geotechnical exploration will result in short-term temporary loss of species habitat; permanent habitat loss will be negligible, resulting solely from the actual bore holes, which will be a series

[1] Habitat conversion is changing one habitat type to another, for example, changing or converting cultivated land to grassland through restoration.

of widely spaced holes, each approximately 8 inches in diameter, which will be grouted. The temporary habitat loss will consist of minor surface disturbances during exploration activities (drilling and exploration trenches) and driving overland, primarily over grasslands and agricultural lands, to access exploration sites. Activities at each site may last up to several weeks depending on location.

A geographic footprint represented in GIS data layers was used to conservatively estimate the area potentially disturbed by geotechnical exploration activities. This footprint consisted of a series of points along the conveyance alignment that were selected based on an assessment of the needs for more detailed geotechnical information. DWR estimates that 1,497 geotechnical exploration sites will be needed to analyze conditions prior to construction. Some of these points fall within areas of proposed conveyance facility construction and others are situated above the proposed tunnels. Based on DWR's experience with these type of activities and some preliminary field estimates, it is expected that the geotechnical exploration sites will result in approximately 0.84 acre of disturbance per site, which includes a 0.23 acre (10,000 square feet) area of temporary disturbance for drilling and staging plus an additional 0.61 acres of temporary disturbance associated with accessing the sites, which will consist of overland travel in agricultural areas and grasslands, which could result in temporary disturbance to vegetation. Figure 6.B-1 shows a typical geotechnical exploration work site. For the analysis, the geotechnical exploration sites, which are represented by points in GIS, were overlain on the conveyance footprint and intersected with the surface footprints and subsurface footprints to establish geotechnical exploration zones (GEZ). Not all surface features were included as part of the surface GEZ because they had not been identified as potential geotechnical exploration sites (i.e., these areas did not have geotechnical exploration site GIS point data within in them). The resulting surface GEZ is 5,980 acres with 913 geotechnical exploration sites and the subsurface GEZ is 1,531 acres with 392 geotechnical exploration sites. This analysis also showed that of the 1,497 geotechnical sites identified only 1,305 represent unique locations (i.e., 192 sites overlapped with at least one other site). The temporary impacts associated with geotechnical explorations within the surface GEZ will be 767 acres (0.84 acre x 913 sites) and within the subsurface GEZ will be 329 acres (0.84 acre x 392 sites). Because the exact locations of these impacts are yet to be determined, estimates were generated by applying the proportion of these impact acreages within the GEZ to the know acreage of modeled habitat within each GEZ. For the surface GEZ, 13% of the area will be temporarily affected (767 acres of impact/ 5,980 acres of surface GEZ) and for the subsurface GEZ 22% of the area will be temporarily affected (329 acres of impact/1,531 acres of subsurface GEZ).

Figure 6.B-1. Example of a Typical Geotechnical Exploration Site

6.B.4.3.1.2 Safe Haven Intervention Work Areas

As described in Section 3.2.3.3.5 *Intermediate Tunnel Access*, safe haven intervention work areas will consist of pressurized safe haven intervention work areas, which will disturb a 0.23-acre area (100 feet by 100 feet), and atmospheric safe haven intervention work areas, each of which will disturb approximately 3 acres. As noted in the PA description, the final determination of both the number and siting of safe haven work areas will depend upon determinations made by the tunnel construction contractors following the completion of geotechnical explorations. The expected number of pressurized safe haven work areas is 31, which will result in approximately 7 acres of disturbance (31 sites multiplied by 0.23 acre). The expected number of atmospheric safe haven work areas will be up to 18, which will result in approximately 54 acres of disturbance (18 sites multiplied by 3 acres) (Chapter 3, *Description of the Proposed Action*, Table 3-8a).

Because the exact location of the safe haven intervention work areas are not known, impacts to species from this activity will need to be approximated. To do this, the subsurface tunnel feature was buffered in GIS; the size of the buffer was based on the size of the safe haven work area. For the pressurized sites, the line was buffered by 50 feet on each side of the alignment to model the width of the 0.23 acre site (approximately 10,000 square feet). This method assumes the 0.23-acre pressurized safe have intervention site will be square, with each side of the square footprint being 100 feet long. The buffering process includes 50 feet from the centerline on both sides of the line, totaling 100 feet. For the atmospheric safe haven work areas, each side of the square site was assumed to be 550 feet and therefore the subsurface tunnel feature was buffered by 275 feet on each side in GIS. The buffered lines were then intersected with the species habitat models to determine the total acres of species habitat that could potentially be affected in each reach. The total acres of the species habitat that overlapped with the tunnel footprint in a given reach were then divided by the total acres of the buffered footprint for that reach. See below for the equation. The proportion of habitat that could potentially be affected by the safe haven intervention work area was then multiplied by the expected acres of impact in that reach to come up with the estimated loss for that reach. This method assumes the highest number of intervention sites in each reach presented in Chapter 3, *Description of the Proposed Action*, Table 3-8a. Although this method may slightly overestimate or underestimate impacts for a specific reach, it is assumed to be conservative because the maximum number of possible intervention sites was assumed.

$$\frac{\text{Total acres of species habitat within the buffered line}}{\text{Total acres in the buffered line}} = \text{The proportion of habitat that has potential to be affected by safe haven intervention sites in that reach.}$$

6.B.4.3.1.3 Barge Landings

As described in the BA Chapter 3, Section 3.2.10.9 *Barge Operations*, the barge unloading facilities will be constructed along waterways adjacent to the conveyance alignment to deliver supplies and materials for construction. The barge landing docks will be approximately 300 feet by 50 feet (approximately 0.34 acre). The exact locations of these facilities will be determined by the construction contractor but generally they will likely fall within the areas identified in Appendix 3.A, *Map Book for the Proposed Action*. Because of the uncertainty of the exact location of these facilities and the amount of space necessary to construct them, the polygons drawn for these areas range between 0.7 acre and 10.7 acres to account for the uncertainty in facility siting within each area. The total temporary impact identified for barge landings in the GIS analysis is approximately 33 acres, which is a conservative estimate based on the anticipated size of the barge unloading facilities (0.34 acre) compared to the sizes of those sites depicted in the mapbooks (0.69 to 10.74 acres).

6.B.4.3.1.4 Transmission Lines

The alignments of the permanent and temporary transmission lines will be chosen through the implementation of AMM30, which provides guidance for establishing the alignments such that impacts to terrestrial and aquatic resources are minimized. Construction of transmission lines will result primarily in temporary impacts from overland travel and equipment staging by construction and installation vehicles (Table 6.B-1). The only permanent effect will be from the approximate 1 foot by 1 foot footprint of the poles and will result in a total of 0.1 acres (Table 6.B-1). The temporary effects from overland travel and staging are not expected to result in ground disturbance such that restoration would be needed. In order to provide an estimate of the temporary habitat loss from pole placement, line stringing and equipment and vehicle staging, a 50-foot wide corridors around the preliminary transmission line alignments were established in GIS and used to intersect the modeled habitat for each listed species. This provides a conservative estimate of the temporary species habitat loss, a premise that was validated by comparing the total acreage resulting from this GIS analysis to the construction details presented in the BA, Chapter 3, Section 3.2.7.2 *Construction*. Table 6.B-1 below summarizes this comparison. As seen in this table, the total footprint from the GIS analysis is twice the amount of impact as that described under the preliminary construction details. However, it is unlikely the temporary impacts will double as a result. Therefore, the transmission line temporary impact estimate provided for this analysis more than covers what the actual, temporary habitat loss will likely be.

Table 6.B-1. Assumptions for Transmission Line Effect Analysis

Transmission Line Size	69 kV	230 kV	TOTAL
Preliminary Construction Details			
Permanent Footprint Size for Pole and Tower Construction (Square feet)	6	30	NA
Temporary Footprint Size for Pole and Tower Construction (Square feet)	5,000	5,000	NA
Temporary Access Route Widths (feet)	12	12	NA
Number of Miles of Line (Permanent)[1]	0	17	NA
Number of Miles of Line (Temporary)[1]	6	30	NA
Total Number of Poles (Permanent)[2]	-	121	NA
Total Number of Poles (Temporary)[2]	71	211	NA
Impacts Based On Preliminary Construction Details			
Permanent Impacts for Permanent Pole/Tower Footings (square feet)	-	3,622	3,622
Total Permanent Impacts for Permanent Poles/Towers Footings (acres)	-	*0.08*	*0.1*
Temporary Impact from Access Routes for Permanent Lines (acres)	-	25	25
Temporary Impact from Access Routes for Temporary Lines (acres)	9	44	52
Temporary Impacts from Temporary Pole/Tower Footings (square feet)	428	6,336	6,764
Temporary Impacts for Temporary Poles/Towers Footings (acres)	0.01	0.15	0.2
Number of current turns deviating by more than 15 degrees and/or 2 miles - Permanent Lines[3]	0	11	NA
Number of current turns deviating by more than 15 degrees/and or 2 miles - Temporary Lines[3]	12	23	NA
Each Conductoring Area Size (square feet)	35,000	35,000	NA
Temporary Conductoring Impact for Permanent Lines (acres)	0	9	9
Temporary Conductoring Impact for Temporary Lines (acres)	10	18	28
Temporary Impacts for Permanent Pole/Tower Work Areas (Square Feet)	-	603,680	603,680
Temporary Impacts for Permanent Pole/Tower Work Areas (acres)	-	13.86	14
Temporary Impacts for Temporary Pole/Tower Work Areas (Square Feet)	35,7121	1,062,336	1,419,457
Temporary Impacts for Temporary Pole/Tower Work Areas (acres)	8	24	33
Total Temporary Impacts for Permanent Transmission Lines (acres)	0	48	48
Total Temporary Impacts for Temporary Transmission Lines (acres)	27	87	113
Total Temporary Impacts for Transmission Lines (acres)	*27*	*134*	*161*
Total Impacts for Transmission Lines (temporary) (acres)	*27*	*134*	*161*
Impacts Based on GIS Analysis			
Total Estimated Temporary Impacts from Permanent Lines Assuming a 50-foot Corridor Width (acres)	-	104	104
Total Estimated Temporary Impacts from Temporary Lines Assuming a 50-foot Corridor Width (acres)	37	182	219
Total Estimated Temporary Impacts (acres)	*37*	*286*	*323*

[a] The 230 kV estimate includes some miles of 500 kV and 230/34.5 kV. Effects from the construction of permanent and temporary lines are considered permanent because the effect will persist for more than one year.

[b] Assumes a pole/tower every 450 feet for 69 KV lines, and every 750 feet for 230 kV lines. Effects from the construction of permanent and temporary lines are considered permanent because the effect will persist for more than one year.

[C] The number of conductoring areas was determined by following the transmission alignments on the maps and noting every 2 miles and/or deviations greater than 15 degrees (this was visually estimated and essentially captures all slight and sharp turns in the lines).

6.B.4.3.1.5 Restoration

Implementation of the California WaterFix (CWF) will require, in part, habitat restoration as compensation for effects to listed species and wetlands. Most of this restoration is designed to comply with the state and federal Endangered Species Acts or section 404 of the Clean Water Act. However, in some cases restoration is needed to comply with the California Environmental Quality Act for impacts to non-listed special status species. Restoration will benefit almost all of the listed species described in this biological assessment. However, during the construction of some restoration projects, there is a potential to temporarily or permanently adversely affect listed species, including the species targeted for benefits by the restoration. Because restoration sites have not yet been selected, a method is needed to estimate the potential for and amount of expected adverse effects to state and federal listed species in the absence of proposed restoration sites.

Implementation of CWF restoration will not affect six federally listed terrestrial species (Table 6.B-4). This conclusion is based on two primary factors, the species habitat does not overlap with the restoration area (e.g., grassland restoration will not adversely affect California tiger salamander because grassland restoration will take place in the north and east Delta where there are no known occurrences of California tiger salamander) or species the habitat will be specifically avoided during restoration (e.g., tidal restoration in Cache Slough would be designed to avoid impacts to vernal pools). See Chapter 6, Sections 6.2 through 6.11, for a description of potential adverse effects from restoration (by species) and the avoidance and minimization commitments in place to avoid and minimize effects.

In limited instances, adverse effects may or will occur to some species from restoration implementation (Table 6.B-4). Although the exact location of habitat restoration is unknown, the general region where restoration will occur is known because of species-specific habitat needs (e.g., bathymetry, tidal elevation, connectivity with occupied habitat, etc.) and the commitment to place compensation lands near the location of effect whenever possible. Table 6.B-5 identifies the restoration projects that will be implemented as part of CWF, the species the restoration will benefit, the region where the restoration is assumed to occur, and the terrestrial species likely to be adversely affected by the restoration.

To improve the accuracy of estimated adverse impacts to terrestrial species from restoration projects, *proxy restoration sites* were used when they were available. A proxy restoration site is defined as a restoration project expected to have similar adverse impacts to the listed species as the restoration that will be implemented for the California Water Fix. Using proxy restoration sites allows for a site-specific evaluation of potential adverse effects to listed species. For the purpose of this assessment, a proxy restoration site must meet the following requirements.

- The proxy restoration site must have a drafted biological assessment or approved Habitat Conservation Plan (HCP) associated with it;
- The proxy restoration sites must affect the same terrestrial species affected by habitat restoration implemented under CWF;
- The proxy restoration sites must be within, or near, the legal Delta;

- The proxy restoration site must be designed to benefit the same species the CWF restoration project will benefit.

- It must have designs that meet criteria detailed under CWF for species-specific restoration siting criteria (see Section 3.4, *Conservation Measures*,).

An example of a good proxy restoration site is the Lower Yolo restoration project; this project will serve as a good proxy restoration site to estimate impacts to giant garter snake from tidal restoration because the project is designed to benefit Delta Smelt and salmonids, the same as with CWF tidal restoration. The Lower Yolo restoration project also overlaps with suitable giant garter snake habitat, occurs in the north Delta/Cache Slough region where CWF tidal restoration will occur, and has an available biological assessment with estimates of giant garter snake habitat loss. Table 6.B-8Table 6.B-8 presents the total loss of giant garter snake and valley elderberry longhorn beetle habitat from tidal restoration estimated using this method. Table 6.B-3 lists the main assumptions used to support the analysis.

For each proxy site DWR and Reclamation created a crosswalk between the habitat types on the proxy site and those used in the CWF. Then, the proportion of the project footprint that will affect species habitat was calculated at the proxy site. The proportion of the restoration project that will affect species habitat is calculated by dividing the amount of adversely affected habitat by the size of the restoration project. The proportion of affected habitat at the proxy site will then be multiplied by the total size of the CWF restoration project. For example, if 2% of the Lower Yolo tidal restoration project would affect high quality giant garter snake habitat, and the total tidal restoration commitment for CWF is 305 acres, then the estimated loss of high quality giant garter snake aquatic habitat from tidal restoration performed under the CWF would be 6 acres (2% x 305 acres).

The proxy restoration project is also be used to inform other determinations of indirect effects in the effects analysis such as construction duration and construction-related effects such as noise, light, and dust. The use of proxy sites to estimate impacts from CWF restoration will be conservative because restoration projects implemented under the CWF are likely to be smaller than what is currently estimated in the draft CWF biological assessment. This is because impacts from CWF construction are currently estimated using conservative habitat models which overestimates impacts (this is in contrast to impact estimates from the proxy restoration sites which use ground surveys to determine impacts). When impacts are measured by a qualified biologist during CWF implementation, the effects will likely be found to be less than estimated. As such, CWF restoration commitments may be reduced commensurate with the reduction in impacts through the Section 7 re-initiation process for federally listed species and through a 2081 permit amendment for state listed species (see Section 3.4.9.1, *Compliance Monitoring*, for more details)

6.B.4.3.2 Construction-Related Effects

There is a potential for individual animals to be harassed, injured, or killed as a result of construction activities. The effects analysis includes a description of the potential for effects, examines how those effects will be avoided or minimized, and evaluates any residual, unavoidable effects after minimization measures are applied. There are two basic types of effects from construction: mortality or injury associated with contact with construction equipment and harassment associated with effects that extend out from construction equipment or personnel and include dust, noise, and light.

6.B.4.3.2.1 Mortality and Injury

Potential construction-related mortality and injury are assessed for each species qualitatively, taking into account the duration that such effects are anticipated to occur, and (when the information is available) the intensity of effect. The analysis then evaluates measures that will be implemented to avoid and minimize these effects, and assesses any residual effects that cannot be avoided.

6.B.4.3.2.2 Harassment, Dust and Light

The effects of dust and light are described qualitatively in each species section. These effects have a limited spatial extent beyond the edge of the construction footprint and are addressed with avoidance and minimization measures. The analysis evaluates the measures that will be implemented to avoid and minimize these effects, and assesses any residual effects that cannot be avoided.

6.B.4.3.2.3 Harassment, Noise

The effects of noise have potential to reach beyond the areas immediately adjacent to the construction footprint. For this reason, a method was developed to characterize noise levels beyond the footprint. For the species with potential to be sensitive to noise—riparian brush rabbit, San Joaquin kit fox, and western yellow-billed cuckoo—the noise levels and potential for effects are described in the effects analysis.

The assessment of potential construction noise levels is based on methodology developed by the Federal Transit Administration (FTA) (2006). Effects associated with construction activities will be temporary, which, for the purposes of this chapter, is defined as occurring during construction, which at most sites is an activity lasting several years (as shown in Appendix 3.D Assumed Construction Schedule for the Proposed Action). Noise levels produced by commonly used construction equipment are summarized in Table 6.B.4.3.2.1-1. Individual types of construction equipment are expected to generate maximum noise levels ranging from 76 to 101 dBA at a distance of 50 feet. The construction noise level at a given receiver depends on the type of construction equipment used and the distance and shielding between the activity and the receiver, which is an individual of a covered species.

An inventory of equipment expected to be in service by project activity type is included in Table 6.B.4.3.2.1-1. The source level is based on the maximum sound pressure level over a defined period (Lmax) of equipment emission levels developed by FTA. Utilization factors for construction noise are used in the analysis to develop 24-hour sound level (Leq) noise exposure values. The Leq value accounts for the energy-average of noise over a specified interval (usually 1 hour), so a utilization factor represents the amount of time a type of equipment is used during the interval. In practice over a multi-year construction schedule, equipment utilization factors for a given hour of a workday will vary from zero to 100%.

To characterize the source level of the worst-case noise condition during a given phase of construction, the six loudest pieces of equipment are assumed to operate simultaneously at a perimeter location, at a receiver distance of 50 feet. Pile drivers are assumed to operate up to 100% of a given hour, assuming multiple drivers are used at a site. Heavy trucks are also assumed to operate up to 100% of a given hour. With the exception of impact pile driving, trucks are assumed to be the dominant source of noise. Source emission levels for trucks are up to 88 dBA at 50 feet, as shown in Table 6.B.4.3.2.1-1.

Other sources of construction noise include machinery noise during installation of power transmission lines, use of helicopters for installing conductor line, use of earth-moving equipment at offsite areas, use of machinery at staging areas, operation of concrete plants, and machinery noise associated with the use of barges for in-water pile driving. Work at excavation sites will involve the use of rock drills, crushers, and screens.

Sheet piles and tubular steel piles will be driven at many project sites. These will be placed using vibratory hammers where feasible but in many cases would also require impact pile driving; since the frequency of use for vibratory hammers is unknown, the pile driving noise analysis assumes that all driving will be performed using impact drivers, which generate louder noise for comparable durations. Some piles will be placed using cast-in-drilled-hole technique; here again the number and location of such piling placements is unknown and the analysis assumes that these would be placed using the louder impact pile driving technique. As shown in Table 6.B.4.3.2.1-1, the source noise level for an impact pile driver is 101 dBA at 50 feet. Construction assumptions for pile driving, including numbers of pile installations per day are included in Appendix 3.E, Pile Driving Assumptions for the Proposed Project. The estimated sound levels from the various construction activities evaluated are a function of distance based on calculated point-source attenuation over “soft” (i.e., acoustically absorptive) ground, such as that found in the action area (hard ground would be bedrock and pavement).

6.B.4.3.2.3.1 Sensitivity to Noise and Thresholds for Mitigation

A 60 dBA is used here as a threshold for effects on covered wildlife species; this threshold is also supported by the California Department of Water Resources (DWR) Section 01570, Specification 05-16 that suggests the following guidelines for DWR construction projects:

Where ambient noise levels are less than 60 dBA and it is determined that construction related noise will cause noise levels to exceed 60 dBA, or where the ambient noise levels are greater than 60 dBA and it is determined that construction related noise will cause noise levels to exceed the ambient level by 5 dBA, a temporary sound wall shall be constructed between the sensitive area and the construction related noise source. The 60 dBA limit is not a regulatory requirement. Although the 60 dBA limit is not a regulatory requirement, it has been established as a threshold for establishing noise impacts by consensus of experts, local and resource agencies, including the U.S. Fish and Wildlife Service (USFWS). It is estimated that among other things, noise levels above 60 dBA may interfere with communication among birds and other wildlife.

Table 6.B4.3.2.1-1. Commonly Used Construction Equipment and Noise Emission Levels for Each Construction Activity

Equipment	Typical Noise Level (dBA) 50 Feet from Source	Equipment Used for Construction Activities								
		Geotechnical Exploration	Safe Haven Work Areas	North Delta Intakes	Tunneled Conveyance Facilities	Clifton Court Forebay	Power Supply and Grid Connections	HOR Gate	Reusable Tunnel Material Areas	Restoration
Pile-driver (Impact)	101			X	X	X		X		
Pile-driver (Vibratory)	96			X	X	X		X		
Grader	85	X	X	X	X	X		X	X	X
Bulldozers	85	X	X	X	X	X	X		X	X
Truck	88	X	X	X	X	X	X	X	X	X
Loader	85	X	X	X	X	X	X	X		
Air Compressor	81			X	X	X				
Backhoe	80	X	X	X	X	X	X	X		X
Pneumatic Tool	85									
Excavator	85	X	X	X	X	X		X	X	X
Auger Drill Rig	85	X	X	X	X	X				
Crane, Derrick	88			X	X	X	X	X		
Compactor (Ground)	82			X	X	X				
Concrete mixer	85			X	X					
Generator	81	X	X	X	X	X				
Pump	76		X	X	X	X				
Roller	74	X		X	X	X		X		

Source: Federal Highway Administration 2006.
dBA = A-weighted decibel.

6.B.4.3.2.3.2 Existing Baseline Conditions in the Study Area

The baseline is the existing ambient noise level in a given location. Baseline noise levels vary greatly depending on the extent of urban development and proximity to transportation corridors. Ambient rural noise levels are typically in the range of 40–50 dB (Table 6.B.4.3.2.1-2). Ambient noise levels near major highways can be as high as 75 dB. Existing traffic noise levels along highways and other major roadways were calculated using peak-hour traffic volume data provided by the project traffic consultant (Fehr & Peers 2015).

Table 6.B.4.3.2.1-2. Typical Ambient Sound Levels as a Function of Population Density

Location	L_{dn} (A-Weighted Decibel)
Rural: Undeveloped	35
Rural: Partially Developed	40
Suburban: Quiet	45
Suburban: Normal	50
Urban: Normal	55
Urban: Noisy	60
Urban: Very Noisy	65

Sources: Cowan 1994; Hoover and Keith 2000.
L_{dn} = day-night sound level.

To assess increases in noise levels due to construction of the project, a baseline of 40 dBA is used to describe the existing ambient noise level in the study area. Because many of the facilities that will be constructed under the PA are located primarily in rural areas, a baseline level of 40 dBA is characteristic of the project's mostly rural setting, and is therefore assumed to apply to the entire action area. The ambient baseline level of 40 dBA is used in this analysis to conservatively account for increases in noise levels. Noise monitoring at specific locations has not been conducted for this project.

6.B.4.3.2.3.3 Construction Noise Effects

The predicted noise levels from construction activities are summarized below in Table 6.B.4.3.2.1-3. Table 6.B.4.3.2.1-4 summarizes the predicted noise levels of construction activities that involve impact pile driving. Discussions of these activities are also provided below.

6.B.4.3.2.3.3.1 Geotechnical Exploration Noise Effects

Potential equipment noise levels from geotechnical explorations are derived by combining the noise levels of the six loudest pieces of equipment that would likely operate at the same time. Assuming 100% utilization within a given hour of day, the combined noise level is 89 dBA Leq (1hr) at 50 feet (Table 6.B.4.3.2.1-3).

6.B.4.3.2.3.3.2 Safe Haven Noise Effects

Potential noise levels at safe have work areas will be comparable to those listed for geotechnical exploration sites in Table 6.B.4.3.2.1-3.

Table 6.B.4.3.2.1-3. Predicted Noise Levels from Construction Activities

Distance Between Source and Receiver (feet)	Calculated Leq (1hr)(dBA)								
	Geotechnical Exploration	Safe Haven Work Areas	North Delta Intakes	Tunneled Conveyance Facilities	Clifton Court Forebay	Power Supply and Grid Connections	HOR Gate	Reusable Tunnel Material Areas	Restoration
50	89	89	96	96	96	91	96	91	91
100	81	81	88	88	88	83	88	83	83
200	73	73	80	80	80	75	80	75	75
400	65	65	72	72	72	67	72	67	67
600	64	64	68	68	68	63	68	63	63
800	**60**	**60**	64	64	64	**60**	64	**60**	**60**
1,000	58	58	62	62	62	57	62	57	57
1,200	56	56	**60**	**60**	**60**	55	**60**	55	55
1,400	53	53	57	57	57	53	57	53	53
1,800	50	50	54	54	54	50	54	50	50
2,000	47	47	51	51	51	49	51	49	49
3,000	46	46	50	50	50	44	50	44	44
4,000	45	45	49	49	49	40	49	40	40
5,280	40	40	43	43	43	40	43	40	40

The 60 dBA thresholds are shown in bold for each activity.

6.B.4.3.2.3.3.3 North Delta Intake Construction Noise Effects

Potential reasonable worst-case equipment noise levels from construction of the intakes are derived by combining the noise levels of the six loudest pieces of equipment that would likely operate at the same time (heavy trucks). Assuming 100% utilization within a given hour of day, the combined noise level is 96 dBA Leq (1hr) at 50 feet (Table 6.B.4.3.2.1-3).

Estimated sound levels from impact pile driving conducted during periods of construction described above are shown in Table 6.B.4.3.2.1-4.

Typically noise from pile driving is not constant; however, because multiple pile drivers would be used, a utilization factor of 100% has been applied. Use of the pile driver simultaneously with noise from other equipment in Table 6.B.4.3.2.1-3 would produce a combined level of 102 dBA Leq (1hr) at 50 feet, as shown in Table 6.B.4.3.2.1-4.

The results shown in Table 6.B.4.3.2.1-4 indicate that during periods of pile driving, wildlife within 2,000 feet of an active intake construction site could be exposed to construction noise in excess of 60 dBA Leq (1hr).

Table 6.B.4.3.2.1-4. Predicted Noise Levels from Construction—Pile Driving and Construction Equipment

Distance Between Source and Receiver (feet)	Calculated Daytime Leq (1hr) Sound Level (dBA)
50	102
100	94
200	86
400	79
600	74
800	71
1,000	68
1,200	66
1,500	63
2,000	**60**
2,500	58
2,800	56
3,000	56
4,000	52
4,500	51
5,000	50
5,280	49

6.B.4.3.2.3.3.4 Tunneled Conveyance Facilities, Clifton Court Forebay, and HOR Gate Noise Effects

Potential reasonable worst-case equipment noise levels from construction work areas adjacent to tunnel conveyance facilities, Clifton Court Forebay, barge landings, and the HOR gate would be comparable to those listed for the North Delta intake sites in Table 6.B.4.3.2.1-3 and Table 6.B.4.3.2.1-4 when pile driving is occurring.

6.B.4.3.2.3.3.5 Power Supply and Grid Connections Noise Effects

Potential reasonable worst-case equipment noise levels from construction of the power transmission lines are derived by combining the noise levels of the three loudest pieces of equipment that would likely operate at the same time (an excavator, a truck and a drill rig for driving micropiles for construction of towers). Assuming 100% utilization within a given hour of day, the combined noise level is 91 dBA Leq (1hr) at 50 feet (Table 6.B.4.3.2.1-3).

The results shown in Table 6.B.4.3.2.1-3 indicates that wildlife within 800 feet of an active power supply and grid connection construction area could be exposed to construction noise in excess of 60 dBA Leq (1hr).

Construction of transmission lines will also include helicopter use for installing conductor line. Use of helicopters will be temporary and intermittent. Two light-duty helicopters are assumed to operate four hours a day to install new poles and lines. Light- to medium-duty helicopters have a source level of up to 84 Lmax at a reference distance of 500 feet (Nelson 1987). It would generally take less than 10 minutes to string the line between each structure. It is estimated that helicopters would not be in any given line mile for more than 3 hours. Given that noise exposure to helicopters would be isolated to line-stringing events, it is not considered to contribute significantly to ambient noise during periods of construction.

6.B.4.3.2.3.3.6 RTM Storage Sites Noise Effects

Potential equipment noise levels from earth-moving activities at RTM storage sites are derived by combining the noise levels of the three loudest pieces of equipment that would likely operate at the same time (an excavator, a truck and a bulldozer). Assuming 100% utilization within a given hour of day, the combined noise level would be 91 dBA Leq (1hr) at 50 feet (Table 6.B.4.3.2.1-3).

The results shown in Table 6.B.4.3.2.1-3indicate that wildlife within 800 feet of equipment operating in the RTM storage areas could be exposed to construction noise in excess of 60 dBA Leq (1hr).

6.B.4.3.2.3.3.7 Restoration Noise Effects

The most noise-producting activities associated with restoration site development are those that entail grading, i.e. the use of earth-moving equipment. Therefore potential equipment noise levels from restoration activities would be comparable to those listed for the RTM storage sites (see Table 6.B.4.3.2.1-3), but would be of much shorter duration (months compared to years at RTM storage sites).

6.B.4.3.2.3.4 Operations and Maintenance Noise Effects

6.B.4.3.2.3.4.1 Operations of Water Conveyance Facilities

Potential pump noise levels during operation of the Combined Pumping Plant was evaluated by calculating sound power levels of the pump based on horsepower (Hoover and Keith 2000). The analysis assumes that air handling units, compressors and emergency generators are integrated into the building structure. Faceplate horsepower for pumps is specified in the Conceptual Engineering Report (see Appendix 3.B). The results shown assume maximum horsepower and flow capacity of the plant. Pump specifications are shown in Table 6.B.4.3.2.1-5. Combined source noise levels assume that pump enclosures (including buildings) provide a nominal 15 dB of noise attenuation. This is a conservative estimate based on masonry construction with openings in the structure for ventilation (Federal Highway Administration 2011). This analysis assumes that pumps are operating 24 hours a day. The estimated sound levels from pump operation are shown in Table 6.B.4.3.2.1-5 below.

Table 6.B.4.3.2.1-5. Pump Specifications

Pump Location	Quantity	Pumping Plant Capacity (cfs)	Pump Horsepower	Individual Pump Source Level (dBA)	Combined Equipment Source Level (dBA)	Assumed Attenuation (dB)	Combined Source Level with Attenuation (dBA)
Clifton Court Forebay Pumping Plant	7	9,000	6,000	98	106	15	91
	2		3,000	95	98		

cfs = cubic feet per second.
dB = decibels.
dBA = A-weighted sound level in decibels.

Table 6.B.4.3.2.1-6. Predicted Noise Levels from Pumping Plant Operation

Distance Between Source and Receiver (Feet)	Intake 2Combined Pumping Plant Calculated L_{eq} Sound Level (dBA)
50	91
100	83
200	75
300	71
400	67
600	63
800	59
1,000	57
1,200	55
1,400	53
1,600	52
1,800	50
2,000	49
2,500	47
2,800	45
3,500	43
4,500	40
5,280	38

Notes: Calculations are based on Federal Transit Administration 2006. Calculation do not include the effects, if any, of local shielding from walls, topography, or other barriers that may reduce sound levels further.

Noise levels assume a nominal pump enclosure attenuation of 15 dB.

dBA = A-weighted sound level in decibels.

The results shown in Table 6.B.4.3.2.1-6 indicate that pump operations would exceed 60 dBA up to approximately 800 feet from the pumps.

6.B.4.3.2.3.4.2 Maintenance Activities

Maintenance activities will be intermittent and generally are not anticipated to result in noise levels substantially above ambient levels in the action area.

6.B.4.3.3 Effects from Operations and Maintenance

There is a potential for individual animals to be harassed, injured, or killed as a result of operation and maintenance activities, including enhancement and management activities on protected lands such as native species plantings and nonnative species control. The analysis of the effects of operations and maintenance includes an assessment of potential effects, an evaluation of measures that will be applied to avoid or minimize effects, and an assessment of any residual, unavoidable effects after the minimization measures have been applied.

This effect category also includes effects of operation and maintenance-related factors such as dust, noise, vehicle traffic, human disturbance, and night lighting, on habitat and individuals potentially present in the vicinity of operations and maintenance activities. Potential operation and maintenance-related effects are assessed for each species, measures that will be implemented to avoid and minimize these effects are evaluated, and any residual effects that cannot be avoided are then assessed.

6.B.4.4 Summarizing Effects on Wildlife and Plants

The effects analysis includes a summary, for each species, of the combined effects of all aspects of the PA. Table 6.B-2 below summarizes suitable habitat loss and proposed compensation as a result of the PA; see Section 3.4.7, *Terrestrial Species Conservation*, for description of all conservation measures and Section 5.7, *Effects Analysis for Delta Smelt and Terrestrial Species*, for description of all adverse effects.

Table 6.B-2. Effects Analysis Methods and Assumptions for Water Conveyance Facility Construction.

Activity/Impact Mechanism	Method of Impact Estimation	Key Assumptions for Purposes of Analysis
Water Conveyance Facility Construction		
Conveyance facilities construction/ permanent removal of habitat	• GIS layer for construction footprint was overlain on modeled habitat and critical habitat GIS layers.	• Construction of the forebay, intakes, permanent access roads, shafts, Clifton Court expansion area result in permanent removal of habitat within construction footprint.
Reusable tunnel material/ permanent removal of habitat	• GIS layer for footprint of reusable tunnel material areas was overlain on modeled habitat and critical habitat GIS layers. • Where AMMs require avoidance of species habitat, this requirement was factored into the impact estimation for species.	• For the purposes of impact analysis, it is assumed reusable tunnel material areas will not be returned to pre-project conditions. • The final footprint for the reusable tunnel material will meet avoidance and minimization requirements in the AMMs.
Conveyance facilities/ Potential Temporary Activities	• GIS layer for footprint of staging areas, intake pipelines, and barge unloading facilities was overlain on modeled habitat and critical habitat GIS layers.	• Staging areas, intake pipelines, and barge unloading facilities are unlikely to be used after construction is complete; however, for the purposes of this analysis, the effects to species are considered permanent. • Subsurface segments of the tunnel/pipeline have no effects on biological resources.

Activity/Impact Mechanism	Method of Impact Estimation	Key Assumptions for Purposes of Analysis
Transmission line construction/ permanent removal of habitat	• GIS layer representing a conservative estimate of the total distance of the transmission line alignment was overlain on modeled habitat and critical habitat GIS layers. • The transmission line footprint assumes a 50-foot corridor to conservatively estimate a maximum take limit.	• Transmission line direct effect will not exceed the maximum take limit which is based on a footprint that extends outside the action area. • Although a significant portion of the transmission lines will be removed upon project completion, due to the 14-year duration of the project, the impact to species habitat will be considered permanent. • Permanent effects to suitable habitat will be primarily from pole placement; tower placement; vegetation clearing around poles, towers, and under lines. • Vegetation clearing is expected to be needed in riparian areas. Grassland and cultivated lands are not expected to require vegetation clearing under transmission lines. • Existing roads will be used for access and maintenance whenever possible. • The effects of overland travel in agricultural areas and grasslands to access pole/tower construction sites and provide maintenance for these facilities will result in minimal temporary disturbance to vegetation (mostly vegetation trampling and minor soil disturbance). No permanent access roads will be necessary, as it is the practice of utilities to only construct permanent access roads in areas of steep terrain and/or areas of dense trees and shrubs.
Geotechnical Exploration Activities/temporary removal of habitat	• Geotechnical exploration sites are assumed to result in 0.61 acre of temporary disturbance along access routes (overland travel) and 0.23 acre of disturbance at each exploration site. Total disturbance per site is assumed to be 0.84 acre. • Up to 1,550 terrestrial sites will be selected for a total geotechnical footprint of 1,302 acres (1,550 sites x 0.84 acre) • Estimated impact determined by the % of the conveyance alignment footprint, for both surface and subsurface footprints, that constitutes geotechnical exploration sites (1,302 acres/conveyance alignment footprint acres).	• Although a small, permanent effect will occur in the form of a cement-filled, drilling hole, all other effects are temporary. • Small, widely scattered, permanent effects from drilling in mostly disturbed locations are expected to be so small as to be insignificant. • Temporary impacts will be primarily from vehicles traveling off road, over land; equipment staging areas; and drilling or shallow-pit excavations. • Shallow pits will be returned to pre-project condition. • Activities are not expected to last more than 21 days at one site.

Activity/Impact Mechanism	Method of Impact Estimation	Key Assumptions for Purposes of Analysis
Safe Haven Work Areas	• GIS layer represents a conservative estimate of the footprints of safe haven work areas. Sizes range from 10.4 to 13.5 acres.	• Some of these areas may fall with in access shaft and tunnel work areas and thus not result in additional impacts • Safe haven work areas will be utilized between 9 to 12 months, and may occasionally exceed one year. • Safe haven work areas will be located to minimize impacts to sensitive terrestrial and aquatic resources.
Barge Unloading Facilities	• GIS layer represents a conservative estimate of the footprints of barge unloading facilities Sizes range from 0.7 to 10.7 acres.	• Each barge unloading facility will be utilized for 5 to 6 years, and will be removed at the end of construction. • Actual locations will be decided by the contractor but likely will fall within the areas identified in the mapbooks in Appendix 3.A, *Map Book for the Proposed Action*.

Table 6.B-3. Effects Analysis Assumptions for Habitat Restoration.

Activity/Impact Mechanism	Impact Analysis Assumptions	Restoration Assumptions: Location and Spatial Extent
Tidal Wetland Restoration—Compensation for Effects on Wetlands (Section 404)		
Inundation/ Permanent loss of habitat	• Unless otherwise stated below, species impacts were estimated by applying the proportion of impacts from a proxy restoration site as described in Section 6.B.4.3.1.5, *Restoration*. Total CWF restoration is estimated to be 1,495 acres, also as described in Section 6.B.4.3.1.5, *Restoration*. • <u>Additional methods below.</u> • Giant garter snake: The giant garter snake habitat in the Lower Yolo Restoration Project Biological Assessment was described as suitable, moderate, and marginal; these habitat types were crosswalked to the high, medium, and low aquatic habitat values in this analysis. Ephemeral aquatic habitat described in the Lower Yolo BA are assumed to be of the same value of all aquatic habitat in this analysis. • Valley elderberry longhorn beetle: acres of estimated impact from tidal restoration were converted to a "number of shrubs and stems" impacted using the method outlined in Table 6.B-10 below. The stem count data (collected during surveys by qualified biologists) is from the McCormack Williamson restoration	Tidal wetland restoration is assumed to be accomplished through the conversion of cultivated lands. • A conservative assumption of the 404 wetland mitigation requirement is 1,200 acres (Mike Bradbury pers. comm.). • Restoration for 404 and Section 7 compensation will occur in the north or east Delta or in the Cache Slough region; restoration in the west and central Delta is also possible.

Activity/Impact Mechanism	Impact Analysis Assumptions	Restoration Assumptions: Location and Spatial Extent
	project where the interior (land side) portion of the levee slopes will be modified. The stem count data is from 3.38 miles of surveyed levee; this is not the entirety of the site but is a large site with a high density of elderberry bushes and for the purposes of this analysis considered adequate. This project requires disturbance to the levee where elderberry bushes are most dense; therefore the proportions developed from these surveys were high. These proportions were then normalized by including the acres of the entire site to be flooded in the proportion equation. See Table 6.B-9 below for the details.	
Vernal Pool Restoration—Compensation for Vernal Pool Crustacean Habitat Loss		
Construction/Permanent loss of annual grasslands, pasturelands, or cultivated lands.	• While vernal pool restoration may temporarily affect San Joaquin kit fox, California red-legged frog, and California tiger salamander, restored and protected vernal pools are expected to benefit the species; no permanent effects are assumed.	• 0.48 acres of vernal pool will be restored in the region west of Clifton Court Forebay[3]. • Vernal pool restoration is assumed to require the conversion of previously disturbed or disked annual grasslands, pasturelands, or cultivated lands.

1 This table of impact analysis methods and key assumptions is not intended to be all inclusive of all activities under the PA. Rather, this table shows how effects were calculated for activities that have effects significant enough to be estimated. Minor activities are described in Chapter 6, *Effects Analysis for Delta Smelt and Terrestrial Species*. Also, the assumptions made are for the purposes of analysis only and reflect reasonable, worst-case assumptions for the PA. Actual footprints of activities may be less than or greater than that assumed and will still fall within the limits of the permits because impacts are within the total range evaluated.

2 Compensation for vernal pool effects may be achieved through a mitigation bank.

Table 6.B-4. Species Habitat that will be Avoided by Restoration Activities.

Species and Habitat	Tidal Restoration	Grassland Restoration for Giant Garter Snake	Nontidal Restoration for Giant Garter Snake	Riparian Restoration for Valley Elderberry Longhorn Beetle	Vernal Pool Complex Restoration	Channel Margin Enhancement
Riparian brush rabbit	X	X	X	X	X	X
San Joaquin kit fox	X	X	X	X		X
California least tern	X	X	X	X	X	X
Least Bell's vireo	X	X	X	X	X	X
Western yellow-billed cuckoo	X	X	X	X	X	X
Giant garter snake		X			X	
California red-legged frog	X	X	X	X		X
California tiger salamander	X	X	X	X		X
Valley Elderberry Longhorn Beetle		X		X	X	
Vernal pool fairy shrimp	X	X	X	X	X	X
Vernal pool tadpole shrimp	X	X	X	X	X	X

[1.] Vernal pool restoration will convert grasslands or pastureland Swanson's hawk foraging habitat to vernal pool/grassland complex, another Swainson's hawk foraging type. An overall loss of foraging habitat is not expected.

Table 6.B-5. Species Habitat that will be Avoided by Transmission Line Construction, Geotechnical Exploration Activities, Safe Haven Work Areas, and Barge Unloading Sites.

Species and Habitat	Transmission Line Construction	Geotechnical Exploration Activities	Safe Haven Work Areas	Barge Unloading Sites	Notes
San Joaquin kit fox					
Least Bell's vireo	X	X			Suitable habitat for least Bell's vireo will be avoided during transmission line construction and geotechnical exploration.
Western yellow-billed cuckoo	X	X			Assume geotechnical and transmission line activities will avoid permanent effects to western yellow-billed cuckoo habitat.
Giant garter snake					
GGS aquatic	X	X			Geotechnical and transmission line activities will avoid permanent effects to aquatic habitat.
California red-legged frog					
California tiger salamander					
Valley Elderberry Longhorn Beetle		X			Geotechnical activities have enough flexibility in implementation to avoid elderberry bushes.
Vernal shrimp	X	X			Geotechnical exploration and transmission line construction will avoid impacts to vernal pool crustaceans and their habitat.

X demarcates species/habitat impacts for activities that could be avoided and that will not require take authorization.
Blank cells indicate that impacts will not be avoided.

Table 6.B-6. Restoration proposed for California Water Fix, Target Species, and Species Adversely Affected.

Restoration Type	Species Benefitting from Restoration	Total Restoration	Location of Proposed Restoration	Terrestrial Species Adversely Affected by Restoration	Mechanism for Adverse Effect to Terrestrial Species
Tidal habitat	Chinook salmon, Central Valley steelhead, green sturgeon, Delta Smelt, Mason's lilaeopsis	305 acres	Cache Slough, North Delta, West Delta	Giant garter snake, valley elderberry longhorn beetle, Swainson's hawk, and Mason's lilaeopsis	Permanent removal of levee that could include aquatic tidal edge and upland cover for the snake and elderberry bushes for the beetle; Permanent flooding of cultivated foraging habitat for the hawk.
Grassland habitat	Giant garter snake	1,044 acres[1]	North and East Delta; in Stoke Lakes, Caldoni Marsh, or in between.	Swainson's hawk	Conversion of high-quality foraging habitat (cultivated land) to moderate quality foraging habitat (grassland)
Nontidal marsh habitat	Giant garter snake and greater and lesser sandhill cranes	625 acres[2]	North and East Delta; in Stoke Lakes, Caldoni Marsh, or in between.	Swainson's hawk	Permanent removal of foraging habitat.
Riparian habitat	Valley elderberry longhorn beetle and Swainson's hawk	100 acres[3]	North Delta, Cache Slough, Along the Sacramento River	Giant garter snake and Swainson's hawk	Conversion of cover/basking habitat (grassland) to non-habitat (riparian)
Vernal pool habitat	Vernal pool fairy shrimp and vernal pool tadpole shrimp	0.90 acres	Byron Hills Region	San Joaquin kit fox, California tiger salamander, California red-legged frog, and Swainson's hawk	Conversion of grassland habitat to wetted habitat
Channel Margin habitat	Chinook salmon, Central Valley steelhead, Mason's lilaeopsis	52,164 linear feet (~5 miles on both sides of the river, 10 miles total)	Sacramento River, Steamboat and Sutter Sloughs, or other locations agreed upon by NMFS and DFW	Giant garter snake, valley elderberry longhorn beetle, Swainson's hawk, and Mason's lilaeopsis	Permanent removal of levee that could include aquatic tidal edge and upland cover for the snake, elderberry bushes for the beetle, and nesting trees for the hawk

1. = 2/3 of giant garter snake upland compensation commitment.
2. = 521 acres of nontidal wetland restoration to compensate for effects to giant garter snake aquatic habitat (783 acres of compensation, 2/3 of which is assumed to be achieved through restoration) + 104 acres of nontidal wetlands to compensate for effects to greater and lesser sandhill crane roosting habitat.
3. = 79 acres of riparian restoration for valley elderberry longhorn beetle and 21 acres for Swainson's hawk nesting habitat; Swainson's hawk compensation assumes that nesting tree replacement will occur within the 21 acres of nesting riparian habitat compensation.

Table 6.B-7. Maximum Habitat Loss and Total, Potential Compensation from Water Conveyance Facility Construction and Protection Habitat Restoration.

Resource	Total Modeled Habitat in the Action Area	Permanent Habitat Loss from Proposed Actions							Temporary Effects		Maximum Effects		Mitigation Ratios		Total Proposed Compensation if All Impacts Occur	
		North Delta Intakes	Reusable Tunnel Material	Head of Old River Barrier	Water Conveyance Facilities	Clifton Court Forebay	Safe Havens	Restoration	Transmission Lines	Geotech Activities	Total Impacts	Total Impacts	Protection	Restoration	Total Compensation, Protection	Total Compensation, Restoration
	Acres	Permanent (Acres)	Permanent (Acres)	Permanent (Acres)	Permanent (Acres)	Permanent (Acres)[b]	Permanent (Acres)	Permanent (Acres)	Temporary (Acres)	Temporary (Acres)	Permanent (Acres)	Temporary (Acres)				
Mammals																
Riparian brush rabbit	n/a[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
San Joaquin kit fox	5,192	0	62	0	4	216	0	11	46	225	293	76	2:1	0:1	586	0
California Least Tern[c]	61,751	37	1	3	34	2,191[b,c]	2	0	9	170	2,268 [c]	179 [c]	0[c]	0 [c]	0[c]	0[c]
Least Bell's vireo [d]	13,062	6	14	0	16	1	0	0	7	10	37 [d]	17 [d]	0[d]	0[d]	0[d]	0[d]
Western yellow-billed cuckoo																
Breeding habitat [e]	1,616	0	6	0	0	0	0	0	1	1	6[e]	2[e]	0:1[e]	0:1 [e]	0[e]	0[e]
Migratory habitat [e]	9,608	5	6	0	11	0	1	0	3	7	23[e]	10[e]	0:1[e]	0:1 [e]	0[e]	0[e]
Total	**11,224**	**5**	**12**	**0**	**11**	**0**	**1**	**0**	**4**	**8**	**29**	**12**	**0:1[e]**	**0:1[e]**	**0[e]**	**0[e]**
Giant garter snake																
Aquatic - High	13,598	0	27	0	29	4	2	0	11	18	61	29	-[f]	3:1[g]	-[f]	183
Aquatic - moderate	12,095	0	3	0	45	11	0	34	1	6	94	7	-[f]	3:1[g]	-[f]	282
Aquatic - low	635	12	53	1	18	2	1	2	6	13	88	19	-[f]	3:1[g]	-[f]	264
Upland-high	32,216	37	81	0	34	0	1	0	18	28	154	46	-[f]	3:1[g]	-[f]	462
Upland-moderate	8,357	17	75	2	75	217	0	44	44	63	430	108	-[f]	3:1[g]	-[f]	1,290
Upland-low	22,046	9	3	0	18	2	1	74	6	6	107	12	-[f]	3:1[g]	-[f]	321
Aquatic Total	**26,328**	**12**	**83**	**1**	**93**	**16**	**3**	36	**18**	**37**	243	**55**	-	3:1[g]	-	**729**
Upland Total	**62,619**	**62**	**159**	**2**	**127**	**219**	**2**	118	**68**	**98**	690	**166**	-	3:1[g]	-	**2,073**
Total	**88,947**	**74**	**242**	**3**	**220**	**235**	**5**	154	**85**	**135**	933	**221**	-	3:1[g]	-	**2,802**
California red-legged frog																
Aquatic habitat	118	0	0	0	0	1[h]	0	0	0[h]	0	1[h]	1	3:1[h]	0:1[h]	3[h]	0 [h]
Upland cover and dispersal habitat	3,498	0	0.1	0	0	46	0	11	12	6	57	18	3:1	0:1	171	0
Total	**3,616**	**0**	**0.1**	**0**	**0**	**47**	**0**	**11**	**24**	**6**	**58**	**19**	**-**	**-**	**174**	**0**
Aquatic habitat (miles)	26	0	0	0	0	0	0	0	0	0	0	0	-	-	0	0
California tiger salamander																
Terrestrial cover and aestivation	12,724	0	0	0	0	46	0	11	7	2	57	11	3:1	0:1	171	0
Valley elderberry longhorn beetle																
Nonriparian channels and grasslands	16,300	31	65	1	57	72	1	0	35	52	227	87 [i]	-[i]	- [i]	0 [i]	0 [i]
Riparian vegetation	15,195	14	14	0	19	1	1	0	8	11	49	19[i]	- [i]	- [i]	0 [i]	79 [i]
Total	**31,495**	**45**	**79**	**1**	**76**	**73**	**2**	**0**	**43**	**63**	**276**	**106**				**79 [i]**
Vernal Pool Crustaceans	89	0	0.2	0	0	6	0	0	0	0	6	0	2:1	2:1/3:1[j]	12	12/18[j]

[a] There is no modeled riparian brush rabbit habitat in the action area. Please see Appendix 4A Species Accounts for detailed information on habitat for riparian brush rabbit.

[b] California least tern habitat loss from Clifton Court Forebay dredging is considered a temporary effect, see Section 6.4, *Effects on California Least Tern*, for more details.

[c] Permanent and temporary loss of California least tern foraging habitat is considered a discountable effect and therefore no compensation is proposed, see Section 6.4, *Effects on California Least Tern*, for more details.

[d] Least Bell's vireo suitable habitat loss will be avoided through design modifications, see Section 6.5, *Effects to Least Bell's Vireo*, for more details.

[e] Western yellow billed cuckoo suitable habitat loss will be avoided through design modifications, see Section 6.5, *California Least Tern*, for more details.

[f] Compensation can be achieved through restoration or protection. The protection component of habitat compensation will be limited to up to 1/3 of the total compensation.

[g] 3:1 mitigation ratio for in-kind mitigation with no limitation as to where it occurs in the Delta. DWR will mitigate at a rate of 2:1 for each, aquatic and upland habitat, if the mitigation is created/protected in a USFWS agreed-to high-priority conservation location for GGS, such as the eastern protection are between Caldoni Marsh and Stone Lakes.

[h] California red-legged frog aquatic habitat loss will be avoided through design, no effects are expected and therefore no compensation is proposed.

[i] The removal of elderberry bushes will be avoided to the maximum extent practicable, however, elderberry bushes may need to be trimmed in the placement of, and also maintenance of, transmission lines. Compensation for these effects are expected to be covered by excess mitigation for the water conveyance facility construction (given the conservative nature of the impact analysis). Geotechnical activities will avoid elderberry bushes. See Section 3.4.7.9.1, *Avoidance and Minimization Measures*, for more details. The impact assessment is based on the loss of elderberry bush stems (and not modeled habitat) and the compensation is based on the required number of transplants, elderberry seedlings, and native plant plantings. See Table 6.10-2 for a complete description of how compensation was determined.

[j] Compensation varies for vernal pool crustaceans, depending on whether the compensation is achieved with by conservation bank/or non-bank means. See Table 6.11-1 for more details.

Table 6.B-8. Total, Estimated Habitat Loss from Tidal Restoration to Giant Garter Snake Habitat using Lower Yolo Restoration Project as a Proxy.

Species/Habitat	Total Impact from Tidal Restoration	Total Acres of Tidal Wetland	Proportion of the Species Modeled Habitat that Overlapped with the Footprint	Acres of Impact by Tidal Wetland Restoration	Acres of Habitat Estimated to be Impacted by Tidal Restoration	Totals to Carry Forward to Impact Table (Rounded Up)
Giant Garter Snake						
Aquatic-High	0	1,643	0.00	305	0.00	0
Aquatic-moderate	183	1,643	0.11	305	33.97	34
Aquatic-Low	11	1,643	0.01	305	2.04	2
Upland-High	0	1,643	0.00	305	0.00	0
Upland-Moderate	236	1,643	0.14	305	43.81	44
Upland-Low	401	1,643	0.24	305	74.44	74

Table 6.B-9. Total, Estimated Habitat Loss from Tidal Restoration to Valley Elderberry Longhorn Beetle Habitat (Elderberry Bushes) using the McCormack-Williamson Project as a Proxy.

Stem diameter (in) at ground level	Exit holes present?	No. of stems in action area[a]	Acres of Habitat Loss	Proportion of Stem Lose at McCormack-Williamson Restoration Site	Acres of Tidal Restoration Estimated for CWF	No. of stems Estimated to be Affected by Tidal Restoration[a]
≥1 to ≤3	No	294	1,364	0.215	305	66
>3 to <5	No	68	1,364	0.050	305	15
≥5	No	11	1,364	0.008	305	2
≥1 to ≤3	yes	111	1,364	0.081	305	25
>3 to <5	yes	41	1,364	0.030	305	9
≥5	yes	4	1,364	0.003	305	1

1. Project disturbance is 18,000 linear feet (3.38 miles) long, assumed the project disturbance width is 50 feet to get an area of total disturbance.

Table 6.B-10. Method for Estimating Effects on Valley Elderberry Longhorn Beetle Habitat.

Step 1. Develop a Shrub/Acre Assumption for Riparian and Nonriparian Habitats from DHCCP Survey Data. 1) 5,304 acres of VELB modeled habitat on DHCCP botanical survey parcels and within boat survey areas (see Assumptions below) 2) Total of 2,638 shrubs estimated from DHCCP survey data (see Assumptions below) 3) Of the 5,304 acres of VELB modeled habitat surveyed, 2,691 acres were riparian and 2,612 acres were non-riparian; 4) 92% of shrubs in DHCCP surveys were classified in Habitat field in data as being in riparian, 4) 2,426 shrubs identified by DHCCP as being in riparian/2,691 acres of modeled riparian habitat = 0.90 shrubs/acre of modeled riparian habitat in survey area 5) 212 shrubs identified by DHCCP as being in "non-riparian" habitat/2,612 acres of modeled non-riparian habitat in survey area = 0.08 shrubs/acre of modeled non-riparian habitat 6) Multiply the number of acres riparian and nonriparian habitat estimated to be lost from the impact analysis by the “shrubs/acre” estimates described under steps 4 and 5. ***Assumptions #1***: areas identified by DHCCP staff as riparian are equivalent to the riparian habitat used in the model. ***Assumption #2***: in data from DHCCP, points with no notes in size classes 1-3 assumed to be one shrub; size class 4 or notes identify a clump assumed to be 3 shrubs; note of several shrubs assumed to be 4 shrubs. Small clumps assumed to be 2 shrubs ***Assumption #3***: all areas of modeled habitat in boat survey areas and botanical survey parcels were surveyed for shrubs ***Assumption #4***: all shrubs mapped fall within modeled habitat for VELB. A cursory review of modeled habitat overlain with DHCCP data reveals that only a small fraction of points fall outside of modeled habitat. ***Assumption #5***: that ditch, riprap, ruderal correspond to modeled non-riparian habitat, possible some of the mapped shrubs are outside of modeled habitat **Note**: DHCCP GIS staff generated survey area for boat by buffering landward by 40 feet, average distance to levee roads approximately 45 feet, shortened area due to limitations in visibility from boat (i.e., vegetation toward top of levee may be obscured, which was mentioned at times in notes)
Step 2. Develop a “Number of Stems With and Without Exit Holes” per Shrub Assumption, for Riparian and Nonriparian Habitats, Using Existing Data from One Project: Southport Sacramento River Early Implementation Project (Southport)[2] Gather VELB data from Southport data collected along the Sacramento River along River Road in West Sacramento (56 shrubs). 1) Calculate the average number of stems per shrub. 2) Calculate average proportion of stems of three diameters (1-3 inches, 3-5 inches, >5 inches) for riparian and nonriparian areas. 3) Calculate the proportion of occupied (presence of exit holes) shrubs for riparian and nonriparian areas. 4) Results

[2] Initially, two projects were used to calculate the stems per shrub and exist holes per stem assumptions, Southport and the State Plan of Flood Control (SPFC) project. However, after reviewing the data, the stems per shrub numbers were far less on the SPFC site than on Southport (4 stems per shrub versus 20 stems per shrub, respectively). This disparity between the two estimates greatly affected the average stems per shrub estimate. It was decided to simply use the Southport data for stems per shrub estimate (20 stems per shrub). This is consistent with the method to create conservative methodologies and impact estimates.

Average Number of stems per shrub		**Average Proportion of Stems by Diameter from Southport**					
Southport	20	Nonriparian			Riparian		
		1-3 inches	1-3 inches	3-5 inches	1-3 inches	3-5 inches	> 5 inches
		56%	23%	21%	67%	17%	16%
Proportion of occupied stems (presence of exit holes)							
Nonriparian				**Riparian**			
unoccupied	7	54%		unoccupied	21	49%	
occupied	6	46%		occupied	22	51%	
total	13			total	43		
Step 3. Apply impacted shrubs estimate from Step 1 to the “combined stems per shrub” assumption (10) in Step 2 to get the number of impacted stems. Then apply the proportional assumptions for “stems by diameter” and “occupied stems” from Step 2 to the number of impacted stems to estimate the number of impacted stems by diameter and by presence of exit holes. See Chapter 6, *Effects Analysis for Delta Smelt and Terrestrial Species*, to see the impact results.							

6.B.5 References

6.B.5.1 Written References

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6.B.5.1.1 Personal Communications

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Attachment 6.B.1, Western Yellow-billed Cuckoo Habitat Assessment

6.B.1 Western Yellow-billed Cuckoo Habitat Assessment

6.B.1.1 Introduction

On August 17, 2015, environmental scientists and biologists from the California Department of Water Resources (Ron Melcer Jr.), U.S. Fish and Wildlife Service (Heather Swinney and Lori Rinek), and ICF International (Rachel Gardiner), conducted site visits within the Action Area and its vicinity where 1) western yellow-billed cuckoo (WYBC) has been observed in recent years, and 2) impacts on riparian vegetation are expected to occur from the construction of the California Water Fix Water Conveyance Facilities. The following locations were visited with the intent of gaining a better understanding of the habitat utilized by contemporary, region specific occurrences: Cache Creek Settling Basin (WYBC) and Putah Creek Sinks (Yolo Bypass Wildlife Management Area, WYBC).

Sites which overlapped with the construction footprint and could be legally accessed were also visited: Intake 2, Intake 3, Intake 5, the barge unloading facility at the south end of Zacharias Island, and several sites identified for the staging of tunnel material. Photos and a summary of each site visit are provided in Section 6.B.1.3. The goal was to inform the analysis to determine the likelihood of adversely affecting WYBC through the loss of riparian habitat during construction. The discussion was focused on whether vegetation at each site could potentially provide breeding and migratory habitat and the rationale for the assessment.

Floodplain disconnection, simplification and loss of riparian vegetation, and loss of geomorphic process in the rivers are all important drivers contributing to the population declines of these two species of birds. Additionally, the condition of these characteristics on the landscape continues to be problematic for WYBC, among other drivers. Impacts on riparian habitat need to be offset and the incremental loss of these habitats even in their poor condition is problematic over the long term. However, there is a low likelihood of occurrence of either species occurring in the action area, the sites are discrete amongst other habitats (primarily cultivated lands), and the quality of the habitat is poor (it is not extensive riparian shrub/forest on a functioning floodplain with a disturbance regime. Therefore, although impacts should be avoided where possible and mitigated where unavoidable from an overall riparian condition standpoint, these impacts would not be adverse to WYBC. The rationale for this determination is discussed below for both breeding and migratory habit in more detail.

6.B.1.2 Habitat Discussion

6.B.1.2.1 Migratory Habitat

Migratory habitat was more difficult to assess. However, there are three main points taken away from the site visits.

1) **The probability of occurrence of WYBC at the specific impact footprint(s) is very low regardless of the condition of the vegetation.** The number of WYBC's moving through the Central Valley is likely very low, potentially less than 30 pairs (see Point Blue's latest survey work on the Sacramento and Feather Rivers; Dettling et al. 2014). The probability that an individual would use the impact sites in question

is quite low given the geographic extent of their migration, and the landscape context at the sites (better options very nearby).

2) **The landscape immediately adjacent to the impact sites provides habitat in sufficient extent to support individuals of either species in the event that an individual did stopover on migration.** Simply put, the WYBC has options, and is already moving around the landscape during migratory stopovers to find the right microclimate, structure, species composition, food etc. A small GIS exercise was conducted with the WYBC impact footprints (n= 52 gis features; 39.75 acres in total). Impact footprints are on average small (mean 0.76 acres; median = 0.48 acres). The footprints comprise a very small component (<0.003%) of the total modeled habitat within the modeling extent (the Delta). Most importantly, for lands immediately adjacent to the impact footprints (within 100 meters), impacted habitat was less than 45% of the habitat on the landscape. If the radius is expanded to 500 meters, impacted habitat was less than 16%.

3) **The vegetation in question does not have the spatial characteristics or dense and heterogeneous structure that = high quality stopover habitat.** Vegetation at the impact sites was for the most part linear in nature (< 2 trees in width) and disconnected from other vegetation, and lacked a developed understory. Sites along the Sacramento River were revetted, lacked a dense understory, and contained non-native tree species which were not part of the model criteria (e.g., *Robinia psuedoacacia*). At tunnel material sites, non-native tree species were present (e.g., *Eucalyptus* spp.), and corridors consisted of rows of single trees many of which were spaced apart and surrounding jet ski ponds. More quantitative assessments could better inform the value that these sites could provide as migration habitat.

6.B.1.3 Sites Visited during the Habitat Assessment

Cache Creek Settling Basin – This site is outside of the action area but it was visited to provide an example of suitable breeding habitat for WYBC. Large, contiguous stands of Fremont Cottonwoods have colonized through frequent inundation and there is dense, young understory primarily consisting of willows. One WYBC was detected at this site in 2005.

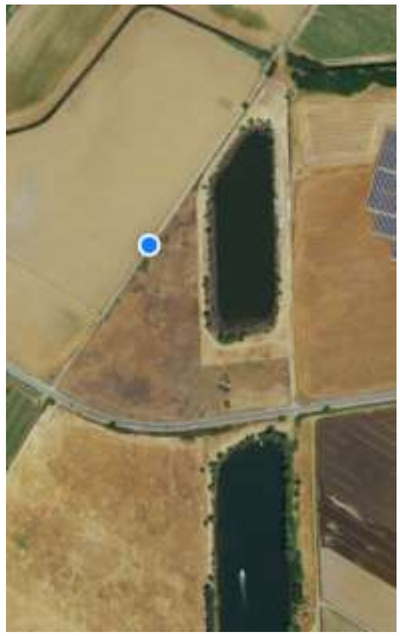
Intake 2 – Riparian habitat along the footprint for the intakes does not provide breeding habitat for WYBC. The vegetation is dominated by non-native speices (Black Locust (*Robinia pseudoacacia)*), is relatively open and lacks a dense understory or the necessary structure to provide suitable breeding habitat for either species.

Intake 3 - Riparian habitat along the footprint for the intakes does not provide breeding habitat for WYBC. The vegetation is dominated by non-native speices (Black Locust (*Robinia pseudoacacia*)), is relatively open and lacks a dense understory or the necessary structure to provide suitable breeding habitat for either species.

Zacharias Island – The eastern edge of Zacharias Island along the Southern Pacific Cut, primarily consists of oaks, which is not suitable breeding habitat for WYBC. The vegetation at the proposed barge unloading facility on the southern end of Zacharias Island is not very complex and is comprised of oaks and grape leaves and is not suitable breeding habitat for WYBC.

RTM Areas – The RTM sites that were visited did not contain any suitable breeding habitat for WYBC. The mature riparian trees at these sites are sparsely distributed and separated from other riparian habitat. The riparian vegetation is relatively isolated and surrounded by cultivated lands. The only understory at two of the sites consisted of marsh vegetation at the pond edges.

6.B.1.3.1.1.1 RTM Triangle A



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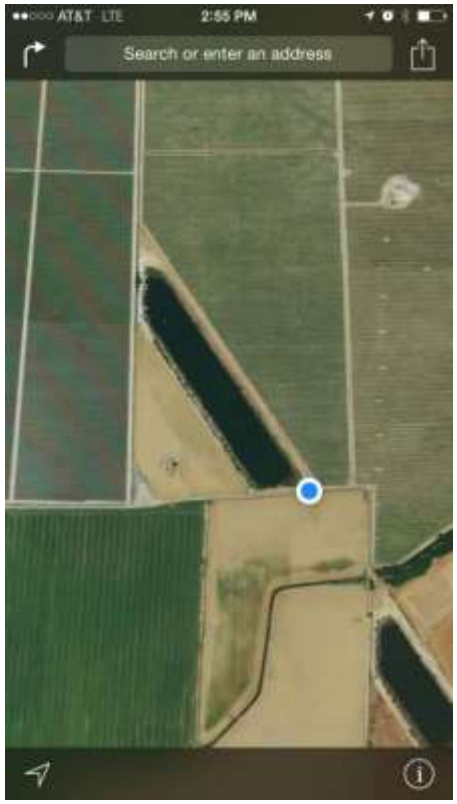
6.B.1.3.1.1.2 RTM Triangle B

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