Attachment 4

California Department of Fish and Game Rationale for Effects of Exports[1]

Introduction & Summary

This document describes the California Department of Fish and Game (DFG) methodology to quantify the surface area in the Sacramento – San Joaquin delta estuary (Delta) that is impacted by the operations of the State Water Project (SWP) and Central Valley Project (CVP) pumping facilities. In order to estimate the mitigation required to offset direct and indirect losses of Fish Species due to impacts to surface acres of aquatic habitat in the Delta accounted to the SWP Delta Pumping Facilities operations, DFG used an analysis based on conclusions and information contained in a manuscript that utilizes the Delta Simulation Model-2 Particle Tracking Model (DSM2-PTM) (Kimmerer and Nobriga, 2008). This methodology provides the general loss of "particles" to the Delta which is a surrogate for loss of productivity and fish life stages vulnerable to these effects.

Assuming a combined export E:I ratio of 0.35, the DFG analysis determined the amount of habitat restoration needed to offset the effects of SWP Delta exports is 12,076 surface acres of aquatic habitat. This is the acreage considered to be impacted as long as diversions continue at the SWP facilities at the identified assumed diversion rates. This analysis further assumes habitat for pelagic species includes open channel and other associated aquatic and intertidal areas that are utilized by various life history stages of pelagic fish species and for food production. The analysis uses flows that result in an E:I Ratio of 0.35 that occur during February 1- June 30, which is the E:I Ratio required by Decision 1641 during that time period. The DFG analysis identified the portion of water exported from the Banks Delta Pumping Plant to be approximately 55.18%[2] of combined Delta exports for the recent years of 2001 through 2006[3]

The actual E:I ratio used to determine the amount of aquatic habitat in the Delta and Suisun Marsh required by DFG as mitigation pursuant to this Amendment will be determined by the final OCAP BiOps and is expected to be between 0.17 and 0.35, depending on operational constraints. Therefore, based on the DFG analysis, the anticipated range of mitigation acreage would be between 8,047 and 12,076 acres.

The methodology described in this paper will be used to quantify the acreage to be acquired by the California Department of Water Resources (DWR) and managed to mitigate impacts to Fish Species caused by the SWP Delta Pumping Facilities. The conclusions drawn here are independent of Kimmerer and Nobriga's conclusions and do not necessarily represent their views.

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[2] DWR 2007. Table of Total Annual Exports at Banks and Bill Jones Pumping Plant 2001-2006 (from DWR Bulletin 132 and DWR Operations Control Office).
[3] This 55.18% includes the portion of CVP water exported through the SWP Banks Pumping Plant.

The following assumptions were used in the Kimmerer and Nobriga paper: 1) DSM2-PTM is an accurate model for Delta hydrodynamics; and 2) particles in the model are representative of pelagic larval Delta smelt. It should be noted that this paper analyzes the combined entrainment effects of both the SWP and CVP pumping facilities and does not attempt to differentiate the individual effects of either facility and assumes that the impacts are directly proportional. 3) The analysis assumed no flow barriers are operating in the Delta. 4) All in-Delta agricultural diversions set to winter values of 0.9 $m^3\ s^{-1}$for the model runs. See Nobriga et al. 2004 and Moyle and Israel 2005 for rationale.

The following is the abstract from “Investigating particle transport and fate in the Sacramento-San Joaquin Delta using a particle tracking model” [Kimmerer and Nobriga, 2008]:

> Movements of pelagic organisms in the tidal freshwater regions of estuaries are sensitive to the movements of water. In the Sacramento-San Joaquin Delta, the tidal freshwater reach of the San Francisco Estuary, such movements are key to losses of fish and other organisms to entrainment in large water export facilities. We used the Delta Simulation Model-2 hydrodynamic model and its particle tracking model to examine the principal determinants of entrainment losses to the export facilities and how movement of fish through the Delta may be influenced by flow. We modeled 936 scenarios for 74 different conditions of flow, diversions, tides, and removable barriers to address seven questions regarding hydrodynamics and entrainment risk in the Delta. Tide had relatively small effects on fate and residence time of particles. Release location and hydrology interacted to control particle fate and residence time. The ratio of flow into the export facilities to freshwater flow into the Delta (export:inflow or EI ratio) was a useful predictor of entrainment probability if the model was allowed to run long enough to resolve particles’ ultimate fate. Agricultural diversions within the Delta increased total entrainment losses and altered local movement patterns. Removable barriers in channels of the southern Delta and gates in the Delta Cross Channel in the northern Delta had minor effects on particles released in the rivers above these channels. A simulation of losses of larval delta smelt showed substantial cumulative losses depending on both inflow and export flow. A simulation mimicking mark-recapture experiments on Chinook salmon smolts suggested that both inflow and export flow may be important factors determining survival of salmon in the upper estuary. To the extent that fish behave passively, this model is probably suitable for describing delta-wide movement, but is less suitable for smaller scales or alternative configurations of the Delta.

Methods and Results

A major effect of the pumps on the Delta can be explained by the Export to Inflow (E:I) ratio, which is the ratio of water export by the SWP and CVP pumping facilities and the amount of inflow into the Delta, or the fraction of inflow that is exported. While this is a simplification of the analysis done by Kimmerer and Nobriga the E:I ratio is a dominant factor in particle fate within the model given enough time for the model to run so that particle ultimate fate can be determined. As the E:I ratio increases (volume of exports nears the volume of inflow), the risk of entrainment increases for particles within the Delta as a whole. Conversely, as the E:I ratio decreases, entrainment risk decreases. Although there is risk due to exports across the entire Delta, the risk differs by release locations throughout the Delta, with risk generally diminishing with increasing distance from the south Delta diversions.

Kimmerer and Nobriga (2008) determined the probability that particles from each release location will be entrained into the SWP and CVP facilities and plotted entrainment risk for each particle release site against the likelihood that particles will be entrained based on calculations in the paper. Groups of locations with similar entrainment risk are color coded (Figure 1). The risk of entrainment increases as E:I ratio increases (Figure 2). These curves are logistic functions fit to the data points output from the particle tracking model. Sites with similar curves were grouped by Kimmerer and Nobriga to illustrate relative entrainment risk for particles from the release sites. These groupings are color coded according to the likelihood that particles will be entrained; green and light green being the lowest risk of entrainment, followed by orange, and than red being the highest. The DFG findings depart from the Kimmerer and Nobriga study on one point. Their analysis divided Franks Tract into the orange group on the east side and the green group on the west side. Recent investigations have suggested to DFG that there is significant tidal trapping effect in Franks Tract (Burau in press). The west side of Franks Tract has a single opening called False River. Particles are forced through False River on the high tide in the west (a narrow opening) into Franks Tract and then disperse into Franks Tract. On the ebb tide the effect is much different with a slow pull of diluted/mixed water downstream from Franks Tract towards the ocean. This is a result of the geometry of Franks Tract. Through reverse flows in Old and Middle Rivers, once a particle is in Franks Tract it has a clear path to the SWP and CVP pumps. For this reason, DFG placed both Franks Tract release sites in the red grouping for acreage purposes (Table 1, Figure 4). GIS software was used to find the acreages of the Delta channels represented by the release locations designated by the color groupings (Table 1, Figure 4).

The percent of particles entrained can be predicted by the logistic function:

$$f(x) = (1 - 1/(1 + a(e^{bx})))$$

where a and b are logistic parameters output from the model runs, and x is the E:I ratio in question.

This function can be run for any E:I ratio and the estimated entrainment risk calculated. The results for an E:I ratio of 0.35 and 0.17 are shown in Table 3. For this analysis 0.35 was used because Water Right Decision D-1641 sets an E:I ratio limit of 0.35 for the SWP/CVP for the months of February though June, with an exception in February following a very dry January. The actual E:I ratio used to determine the amount of aquatic habitat in the Delta and Suisun Marsh required by DFG as mitigation pursuant to the DFA Amendment will be determined by the final OCAP BiOps and is expected to be between 0.17 and 0.35, depending on operational constraints. These entrainment percentages (Table 3) were then averaged for locations within each color grouping (P) and these averages were multiplied by the channel surface area (Table 2) represented by that color group (A) to determine the extent of habitat affected (E, rounded to the nearest acre) (Table 4). The total habitat impacted, the sum of the color groups (E), by combined pumping of the SWP and CVP at an E:I ratio of 0.35 is shown in Table 4.

This is defined in the following area of effect equation:

$$A(P) = E$$

Table 1. Release locations of particles and their relative entrainment risk (green = least entrainment risk, red = greatest). Color groups conform to Kimmerer and Nobriga, 2008, except for Frank's Tract west and Frank's Tract east.

Green	Light Green	Orange	Red
Three Mile Slough (X3M)	Hood (Hoo)	N. Fork Mokelumne (NFM)	S. Fork Mokelumne (SFM)
Ryde (Ryd)	Twitchell Island (Twi)	Georgiana Slough (Geo)	Potato Slough (Pot)
Rio Vista (Rio)			Stockton (Sto)
Collinsville (Col)			Medford Island Med)
Antioch (Ant)			Victoria Canal (Vic)
			Vernalis (Ver)
			Bacon Island (Bac)
			Mossdale (Mos)
			Franks Tract West (FTW)
			Franks Tract East (FTE)

Table 2. Total acres for each zone. Term A for the previous equation is found in the second column.

Delta zone (color code)	Channel Area (acres)
	A
Lower Sacramento (green)	19,140.69
Hood and West Delta San Joaquin (light green)	6,080.929
Georgiana / N. Fork Mokelumne (orange)	2,704.28
San Joaquin (red)	21,124.31
Total	49,050.209

Table 3. Percent particle loss at SWP/CVP at indicated E:I ratio. Each loss color group is averaged to get the term P shown in Table 4.

Release Location	Loss at 35% E:I	Loss at 17% E:I
Antioch	0.028898	0.008604
Collins	0.015794	0.004259
RioVis	0.074023	0.023395
Ryde	0.10951	0.035383
X3Mile	0.118093	0.0427
Hood	0.232942	0.093378
Twitch	0.241985	0.091961
GeoSlu	0.437069	0.166755
NFMok	0.438728	0.173957
Bacon	0.999986	0.926758
Franks103	0.463108	0.210794
Franks226	0.183297	0.076283
Medford	0.999135	0.68729
Mossdale	0.9992	0.911586
Potato	0.985028	0.479754
SFMok	0.860642	0.31332
Stockton	0.998728	0.685707
Vernalis	0.999364	0.920197
Victoria	1	1

Table 4. Impacted acres of Delta channels weighted by percent particle loss at E:I ratio of 0.35. This table shows the results of the equation A(P) = E. The total area of affect for this analysis is 21,885 acres.

Zone of Influence Totals	Acres	Average % Particle Loss	Acres of Loss
	A	P	E
Sacramento (green)	19,140.69	0.06926321	1,326
West Delta San Joaquin (light green)	6,080.929	0.237463637	1,444
Georgiana / N. Fork Mokelumne (orange)	2,704.28	0.437898719	1,184
San Joaquin (red)	21,124.31	0.848848811	17,931
Total	49,050.209		21,885

Discussion

Kimmerer and Nobriga indicate that this model may or may not be a good indicator for the entrainment of salmon smolts that are out-migrating because their behavior likely makes their fate depart substantially from neutrally buoyant particles. Salmon fry do enter the central Delta through the Delta Cross Channel and Georgiana Slough similarly to particles in the model and salmon smolt survival in the central delta is lower than in the mainstem of the Sacramento River (Brandes and McLain 2001). Fish that migrate through the central Delta incur higher mortality. Currently, juvenile Chinook salmon that enter the central Delta show lower survival rates than juveniles that stay in the main stem of the Sacramento River (Brandes and McLain 2001). The exact reasons for this are unknown: however local conditions such as predatory fish and changed hydrology are the most likely causes. Vogel (ERP 2004) showed that predation rates on Chinook salmon in Georgiana Slough were 82.1% verses the lower Sacramento main stem at 25%. Increased temperature in the central Delta where flows are low may also be a contributing factor in lowered survival of both salmon and delta smelt during certain times of the year.

However, for delta smelt larvae less than 20mm Kimmerer and Nobriga indicate that the particle tracking model provides good predictions for their movement, assuming that the underlying hydrodynamic model is accurate, and suggests that for the months of March through May measures could be taken to reduce their entrainment when E:I ratios are at 0.35 (D-1641). This analysis is also generally representative of pumping effects on longfin smelt in dry years when spawning and larval fish occur in the west and central Delta during similar time periods, although longfin smelt may appear 1-2 months (Dec. and Jan.) earlier when the E:I ratio is at 0.65. This analysis does not take into account the effect of the pumps on elements of delta smelt critical habitat in the estuary such as nutrients, primary production, and secondary production. Primary production in Suisun Bay is dominated by allochthonous sources (Jassby 2008). The Delta is a net producer of organic matter to downstream areas in critically dry years (Jassby and Cloern 2000). However, the SWP/CVP facilities export a portion of this production and the resulting Delta transport of organic matter to Suisun Bay is less than what enters from upstream sources like the San Joaquin River (Jassby and Cloern 2000).

Conclusion

From this analysis, DFG has determined that the total amount of Delta wetlands affected by the CVP and SWP pumping activities is 21,885 acres of marsh if pumping rates are at a 0.35 E:I ratio.

Literature Cited

Kimmerer, W. J., and M. L. Nobriga. 2008. Investigating Particle Transport and Fate in the Sacramento-San Joaquin Delta Using a Particle Tracking Model. San Francisco Estuary and Watershed Science [online serial] 6, no. 1 (February).

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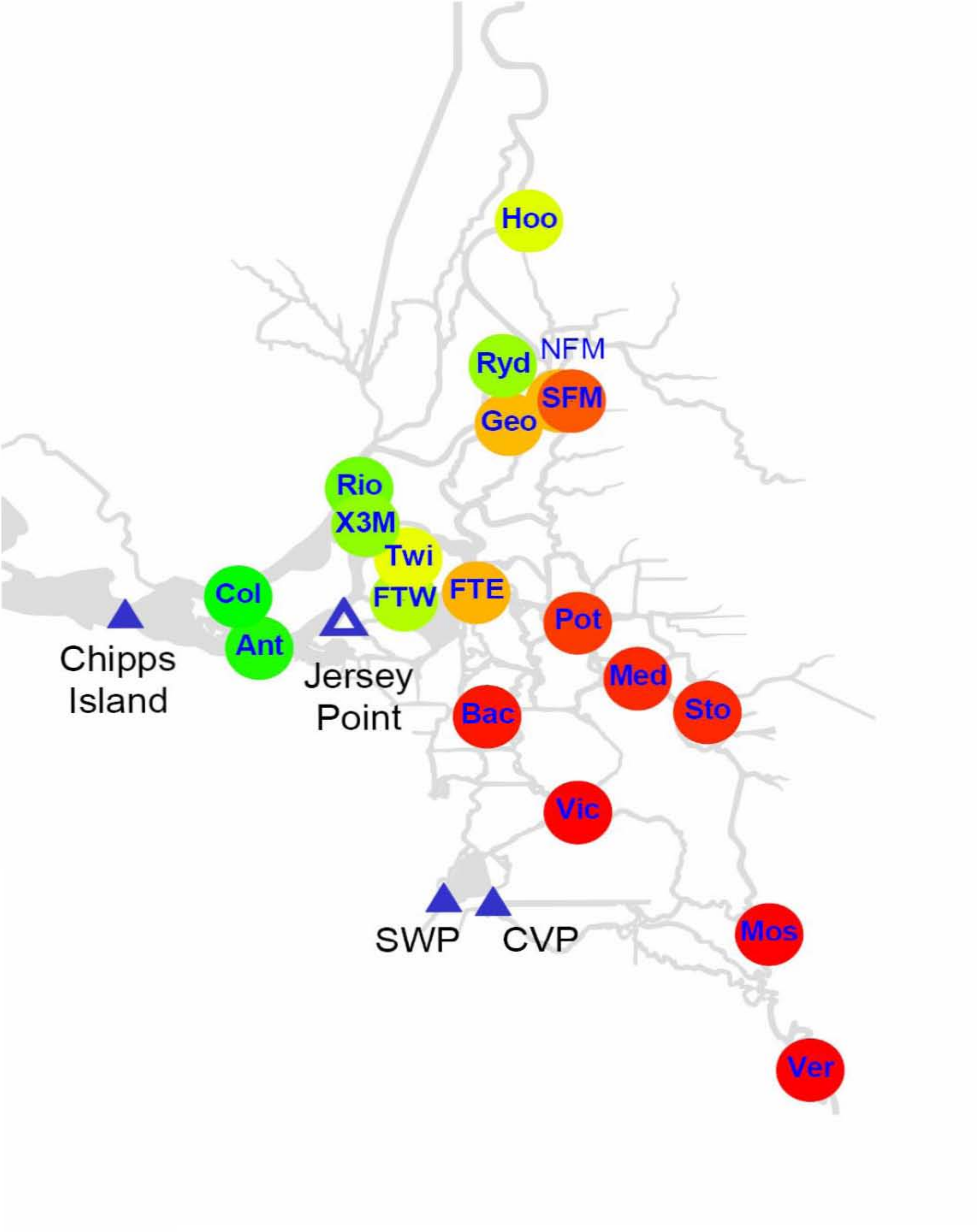

Figure 1. This figure shows release locations and their grouping by entrainment risk according to Kimmerer and Nobriga (from Kimmerer and Nobriga, 2008, figure 1).

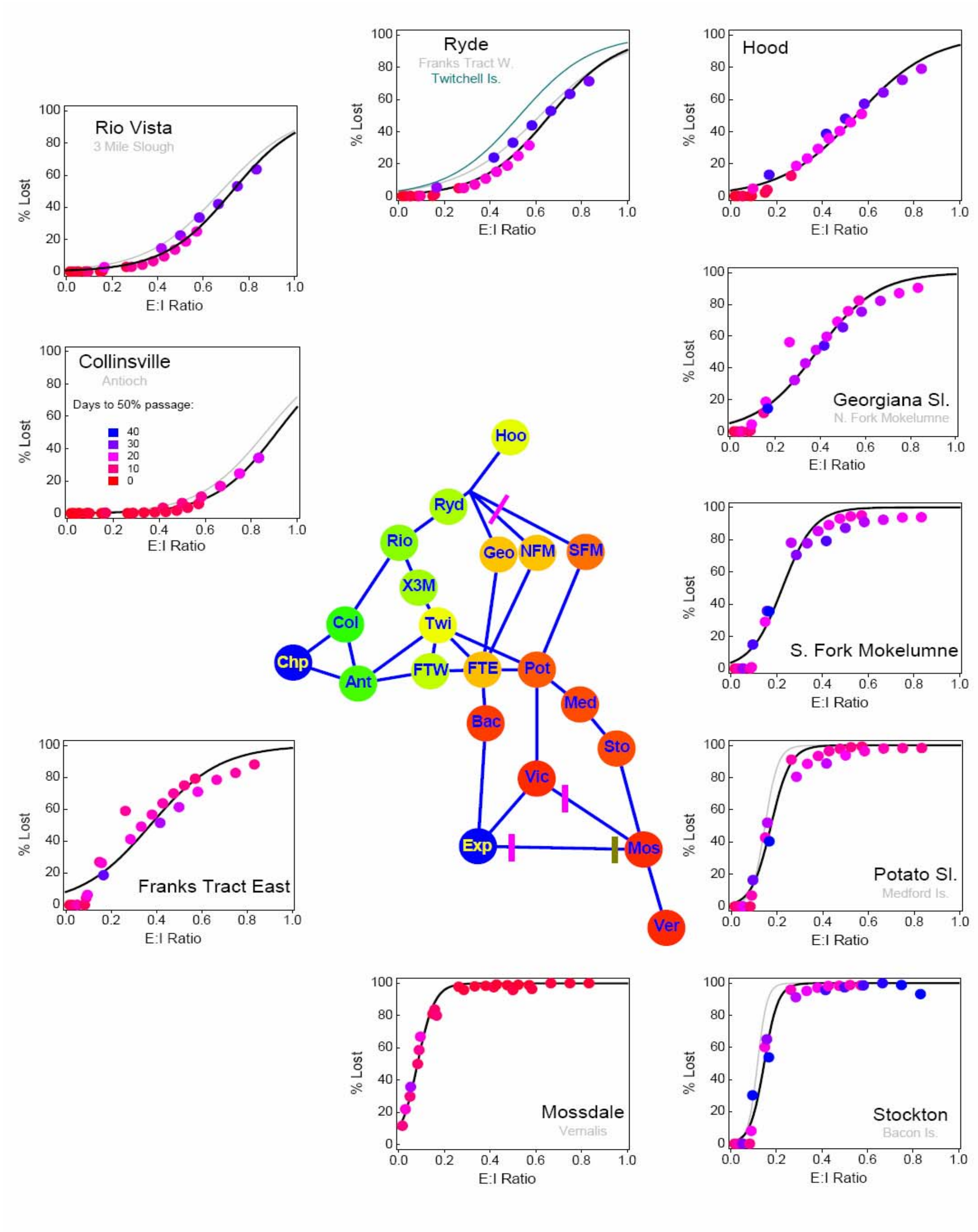

Figure 2. Logistic curve fits to the particle tracking entrainment data. E:I ratio is on the x axis and percent lost to pumping is on the y axis. (from Kimmerer and Nobriga, 2008, figure 7).

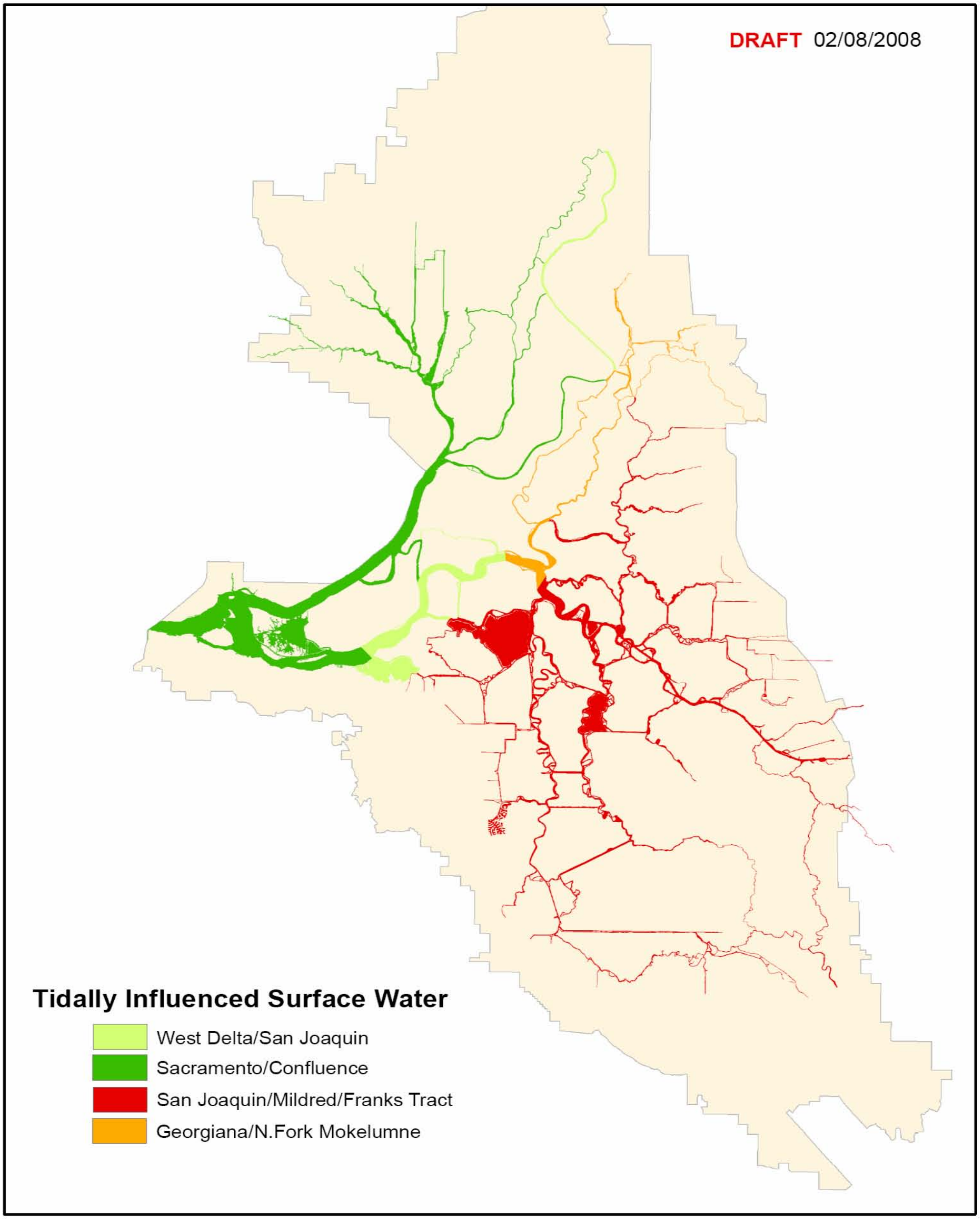

Figure 3. Area of effect as defined by entrainment risk and GIS software (DFG).