Excerpts from the

State Water Resources Control Board

1987-8 Water Quality Control Plan

And 1992 Bay/Delta Water Rights

Proceedings

Annotated Excerpts From Testimony

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Documents from which excerpts are taken

Preface

Each exhibit from earlier proceedings that is quoted in this document addresses one or more key elements that have recurred in the discussion of Delta outflow over a period of twenty years or more. However, the excerpts contained in this document do not attempt to present a complete picture of the flow needs of the Bay-Delta ecosystem.

1

McAdam, Steven, Assistant Executive Director, San Francisco Bay Conservation and Development Commission, "*Testimony to the State Water Resources Control Board on 'Impacts of Freshwater Inflow on San Francisco Bay' for the Phase I Hearings, September 24, 1987*" (BCDC-Exhibit 2, submitted copy bundled with BCDC-Exhibit 7)

Mr. McAdam refers to the BCDC San Francisco Bay Plan:

The San Francisco Bay Plan recognizes the delicate relationship between fresh and salt water … the Bay Plan states that diversions of freshwater should not reduce the freshwater inflow into the Bay to the point of damaging the oxygen content of the Bay, the flushing of the Bay, or the ability of the Bay to support existing wildlife. *(p. 3)*

Some of the effects of reduced freshwater inflow to San Francisco Bay are discussed, noting the connection with San Francisco Bay pollution:

The San Francisco Bay/Delta estuarine system has been severely degraded by the loss of wetlands, pollution, and reductions in freshwater inflow. Of importance to this hearing, the existing reduction in Spring and Summer flows into the Bay, combined with the effects of water regulation upstream, has had many significant effects on the estuary, including: [effects to salmon, striped bass, phytoplankton, waterfowl and wildlife, and accumulation of toxic pollutants in clams and shellfish are enumerated]. *(p. 4)*

On behalf of BCDC, Mr. McAdam proposes ***eleven measures.*** *Similar recommended measures appear throughout the history of SWRCB Bay-Delta proceedings, although* ***the connection with San Francisco Bay is often forgotten****:*

1. Revise the existing flow standard to provide greater Sacramento flows to allow outmigration of salmon in the spring;

2. Enact a new flow standard for the lower San Joaquin River to allow outmigration of salmon in the Spring;

3. Enact a new flow standard to eliminate or significantly reduce flow reversals in Delta channels due to export pumping to protect salmon and striped bass;

4. Revise the existing D-1485 flow standards to protect striped bass spawning and survival and to restore them to historic levels;

5. Enact a new salinity standard to maximize phytoplankton abundance in the late Spring and Summer by positioning the entrapment zone in Suisun Bay;

6. Enact a new salinity standard to maximize phytoplankton abundance in the late Spring and Summer by preventing the establishment of marine benthic organisms in Suisun Bay;

7. Re-enact the original salinity standard under D-1485 to protect managed brackish wetlands and waterfowl around Suisun Bay (as previously recommended);

8. Enact a new salinity standard to protect brackish tidal wetlands and their associated wildlife around Suisun Bay (as previously recommended);

9. Enact a new flow standard to maximize phytoplankton abundance in San Pablo Bay during the Spring;

10. Enact a new salinity standard to maximize phytoplankton productivity in the South Bay during the Spring;

11. Enact a new salinity standard to minimize residence times of pollutants in the South Bay in Winter and Spring.

(pp. 5-6)

Smith, Lawrence H., "*A Review of Circulation of Mixing Studies of San Francisco Bay, California*," U.S. Geological Survey Open-File Report 87-534, 1987 (USGS Exhibit No. 3)

Mr. Smith diagrams the function of Delta inflow in creating circulation in South San Francisco Bay:

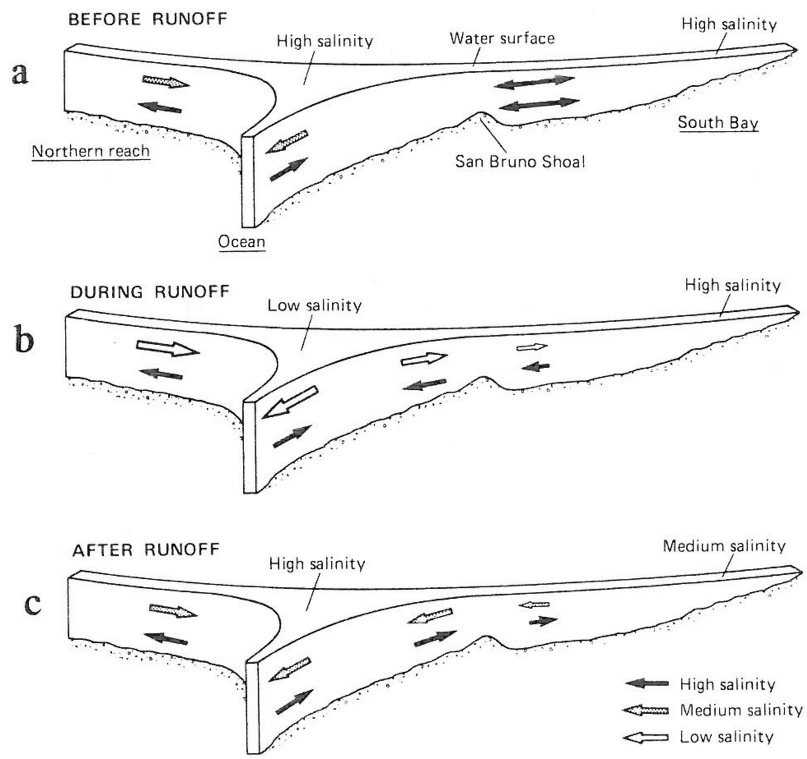

FIGURE 13.--Idealized summer (a) and winter (b and c) patterns of landward-seaward net currents in the channels of South Bay (McCulloch and others, 1970). During summer the lack of a salinity difference between Central and South Bays leads to oscillatory net currents (a). During winter, when large delta discharges lower the salinities of Central Bay below those of South Bay, gravitational exchanges between the two embayments are induced (b). After runoff events, when the ocean-bay exchange elevated the salinities of Central Bay above those of South Bay, the direction of gravitational exchange is reversed (c).

(p. 27)

Mr. Smith summarizes the influence of Delta inflow on mixing in San Francisco Bay:

The influence of delta discharge on San Francisco Bay is evident from the high differences in circulation and mixing characteristics between low and high discharges (table 2). During low delta discharges the northern reach is characterized by gravitational circulation (fig 9a and 10) seaward of the null zone, which is usually located in Suisun

Bay. The presence of large shallow areas adjacent to the channels causes net horizontal circulation, and particularly the induced shallow-channel exchange, to be important as well. Mean residence times on the order of a month for each embayment result from a combination of seaward flow induced b delta discharge and by the diffusive effects of the circulation mechanisms (fig 15). During this period salinity differences between Central and South Bays are negligible, so that tines and wind determine the characteristic net horizontal circulation in South Bay (fig 12). These mean circulation characteristics and exchanges with Central Bay cause the mean residence time of South Bay to be on the order of a few months, but uncertain.

During high delta discharges the null zone in the northern reach moves rapidly seaward during runoff events and returns landward more slowly under the control of gravitational circulation and net horizontal circulation. Mean residence times for the entire northern reach are reduced from months to weeks or days and are controlled almost entirely by delta discharge (fig 15). The arrival of low-salinity surface water in Central Bay during runoff events induces gravitational circulation in South Bay (fig 13), increasing its exchange rate with Central Bay. The duration of this increased exchange and the southward penetration of the fresh water are dependent on the magnitude of the discharge event. Under these conditions the mean residence time for South Bay can be reduced from months to a few weeks.

(p. 34)

3

Rozengurt, Michael, Herz, Michael J., and Feld, Sergio, "*Summary, The Role of Water Diversions in the Decline of Fisheries of the Delta - San Francisco Bay and other Estuaries*," September, 1987. Technical Report 87-8. Exhibit 21 of the Romberg Tiburon Center for Environmental Studies in the SWRCB Water Quality Control Plan hearings, September, 1987. (Exhibit TIB-21)

[This document is a summary of a much more extensive, 448-page report of the same name (Technical Report 87-7).]

Rozengurt et al begin by providing sobering historic context:

"Published results regarding water development in rivers entering the Black Sea, Sea of Azov, Caspian and Mediterranean Seas in Europe and Asia all point to the conclusion that when successive spring and annual water withdrawals exceeded 30% and more than 40-50% of the normal unimpaired flow respectively, (computed as the average for 50-60 years of observations), water quality and fishery resources in the river-delta-estuary-coastal zone (ocean) ecosystem deteriorated to levels which override the ability of the system to restore itself." *(p. 1)*

Rozengurt et al summarize for the 1987 hearings the role of diversions in the decline of Bay-Delta fisheries (and in the decline of other fisheries worldwide):

Under natural conditions approximately 60-70% of the flow takes place during this [late winter and spring] period, and this flow is responsible for:

1) Repelling the intrusion of sea water into the Delta;
2) Providing necessary levels of nutrients (organic and inorganic materials, phosphate, silicates, nitrogen, etc.);
3) Producing flow conditions necessary for anadromous fish migration, spawning and rearing;
4) Creating a large entrapment zone which optimizes survival of fry and the food on which they feed;
5) Providing flushing and mixing flows to maintain water quality conditions (dissolved oxygen and temperature throughout the water column), and
6) Entraining large amounts of salty water as it flows through the estuary to the ocean, creating a dynamic salinity equilibrium within the system.

Although all of these conditions play important roles in the hatching and development of fish of a given year class, it is extremely important to note that the state of the estuary during this period is heavily influenced by past runoff conditions as well.

(p. 3)

In the 1987 hearings, Rozengurt et al make the following recommendations:

"…We propose the following criteria for mean spring and annual regulated Delta outflows which must be maintained for periods of at least 2-3 consecutive years:

A. Total spring regulated Delta outflow = 6.9-7.5 MAF or mean spring (April+May+June/3) flows of at least 2.3-2.5 MAF (64.1-69.6% of the normal spring delta outflow, Q = 3.59 MAF) or 38,653 – 42,014 cfs.

B. Total annual regulated outflows no less than 17-19 MAF (62.5-69.8% of the Q = 27.2 MAF)."

(p. 16)

4

Williams, Dr. Philip B., "*A Salinity Standard to Maximize Phytoplankton Abundance by Positioning the Entrapment Zone in Suisun Bay*," September 23, 1987, on behalf of the Contra Costa County Water Agency and Environmental Defense Fund (CCCWA/EDF Exhibit 1)

Dr. Williams presents analysis of the base of the food chain in the estuary and how to maximize phytoplankton abundance in Suisun Bay. His conclusions are as follows:

A. Phytoplankton are the base of the estuarine food chain in Suisun Bay, and directly affect the abundance of many other organisms, including shrimp, striped bass, and many resident fish. Maintenance of phytoplankton abundance is critical to maintaining populations of higher level organisms in Suisun Bay.

B. The abundance and distribution of key zooplankton species including Neomysis and Eurytemora, are controlled by phytoplankton abundance in the channels of Suisun Bay.

C. The abundance of phytoplankton, particularly diatoms, in the channels of Suisun Bay is controlled by the positioning of the entrapment zone adjacent to the shallows of Suisun Bay.

D. The abundance of phytoplankton in Suisun Bay is also affected by the intrusion of marine benthos, such as soft-shelled clams, or marine worms during periods of higher salinity.

E. The positioning of the entrapment zone is dependent on the location of the null zone, which is directly affected by Delta outflow.

F. The entrapment zone is located adjacent to the shallows of Suisun Bay when the null zone is located adjacent between Port Chicago and Chipps Island.

G. In order to maximize phytoplankton abundance in Suisun Bay throughout the year, the entrapment zone should be located adjacent to the shallows of Suisun Bay for the period April until September, except when higher flows are required for phytoplankton and for beneficial uses in other parts of the San Francisco Bay-Delta estuary.

H. A tidally averaged bottom salinity standard should be adopted that will locate the entrapment zone adjacent to the shallows of Suisun Bay. The recommended standard is a 28-day tidally averaged mean bottom salinity at Chipps Island, not to exceed 2 ppt. total dissolved solids for the period April through September, except in a one-in-twenty dry year.

(pp. 4-5)

Williams, Dr. Philip B., "*A Flow Standard to Maximize Phytoplankton Abundance by Positioning an Entrapment Zone in San Pablo Bay*," September 23, 1987, on behalf of the Contra Costa County Water Agency and Environmental Defense Fund (CCCWA/EDF Exhibit 1)

Dr. Williams draws connections in this document between Delta outflow and productivity at the bottom of the food chain in San Pablo Bay. Among his conclusions:

C. An entrapment zone appears to form in the channel in the vicinity of the Pinole shoal when there is sufficient Delta outflow.

D. The highest concentrations of phytoplankton occur in the channel [main channel of San Pablo Bay] when Delta outflows are approximately 20,000 cfs.

H. In years which do not have sufficiently high winter Delta outflow, it appears that marine benthos can survive through the winter, resulting in high biomass during the following season, which significantly reduces phytoplankton biomass, even though Delta outflows may be sufficient to establish an entrapment zone the following spring.

J. A salinity standard that would optimize phytoplankton abundance in San Pablo Bay is as follows: maintain the 28-day running average of Delta outflow to be not less than 20,000 cfs during the period April through June. The standard should apply in all years except in years when the unimpaired Delta outflow for the prior October through march period is less than the 30 percentile dry year, as determined by the average October-through-March unimpaired Delta outflow.

(pp. 3-4)

5

Bobker, Gary, The Bay Institute, "Comments of the Bay Institute of San Francisco on Proposed USEPA Rule: Water Quality Standards for Surface Waters of the Sacramento River, San Joaquin River, and San Francisco Bay and Delta," March 10, 1994.

In the 1994 hearings for the US EPA water quality standards, Mr. Bobker emphasizes the importance of maintaining X2 well west in Suisun Bay in order to provide adequate habitat for delta smelt:

The Bay Institute is concerned that the proposed Estuarine Habitat criteria fail to require a sufficient number of days of compliance at Roe Island in dry and critically dry years…. Roe Island is the most ecologically significant of the three compliance stations proposed by EPA for the Estuarine Habitat criteria. Because of Roe Island's central location in Suisun Bay, attainment of the Roe Island criteria is strongly linked to the maxima of low salinity habitat. Placing the 2 ppt salinity isohaline at Roe Island ensures that, as the entrapment one and X2 fluctuate in position upstream and downstream in response to the tidal prism, low salinity habitat is maintained in the broad, shallow reaches of Suisun Bay and its sub-embayments, Grizzly and Honker Bays.

Attaining the maxima of low salinity habitat in central Suisun Bay provides both direct and indirect benefits to numerous aquatic organisms. Direct benefits are provided for species which have low salinity habitat requirements, such as Delta smelt. Suitable rearing habitat for Delta smelt occurs when the 2 ppt isohaline occurs in Suisun Bay, i.e., the area west of Chipps Island (FWS, 1994), and Delta smelt abundance has been found to be most closely correlated to the occurrence of the 2 ppt isohaline in the reach from Roe Island to Middle Ground (Herbold, 1994).

(p. 5)

… Meeting the criteria at Chipps Island alone in critically dry years or in years when the Roe Island standard is not triggered fails to ensure adequate habitat in Suisun Bay. *(p. 6)*

6

California Department of Fish and Game, "*Written Testimony, Delta Smelt*," June, 1992, for the SWRCB Interim Water Rights hearings (WRINT-DFG Exhibit 9)

This testimony describes the life history of Delta smelt and explains the interaction between this species and Delta operations and flows.

*Of **life history**, the document states:*

After hatching, the larvae are negatively buoyant but as the air bladder begins to develop, the larvae float and drift with the currents downstream to the entrapment zone or to other areas of the Estuary depending on flow conditions (e.g., outflow, exports, agricultural diversions, etc.). In the entrapment zone, the mixing effect allows the larvae to remain instead of being swept into salt water. This zone also traps large numbers of zooplankton on which they are able to feed, and it location is important to the young of many fish species, hence the term "nursery area." Recently, the entrapment zone has been confined to small channel areas of the Delta due to low inflows and high water exports. Larval growth is rapid and juveniles may reach lengths of 40-50 mm (FL) by August. *(p. 4)*

*Geographic distribution of Delta smelt is variable, but both **the distribution and population of Delta smelt have been shrinking**:*

The geographical distribution of delta smelt during the summer and fall is strongly influence by delta outflow. As flows increase and saltwater is repelled, more of the population occurs in Suisun and San Pablo bays and less occurs in the Delta. There is reason to believe that delta smelt benefit from being transported to Suisun Bay. Historically, when delta smelt were more abundant an large proportion of the population was found in Suisun bay and the surrounding areas…

Information from seven independent data sets has demonstrated a dramatic decline of the delta smelt population and low population levels since 1983. *(p. 5)*

Historically, when the population was at higher levels the population was distributed more widely throughout the Estuary, suggesting that more suitable habitat was available to delta smelt in those years. *(p. 6)*

*The testimony describes on pp. 8-12 "*Factors potentially responsible for the Delta smelt decline," *providing analysis under each of the following categories*: "Food Supply," "Low Spawning Stock," "Entrainment in Water Diversions," "Flows out of Optimal Range," "Toxic Substances," "Genetic Dilution," [and] "Competition and Predation."

7

California Department of Fish and Game, "Estuary Dependent Species: Exhibit WRINT-DFG-Exhibit #6 entered by the California Department of Fish and Game for the State Water Resources Control Board 1992 Water Quality/Water Rights Proceedings on the San Francisco Bay/Sacramento – San Joaquin Delta." 1992, month not given. (WRINT-DFG-Exhibit 6)

The document describes ***correlations between flows and abundance*** *of several estuarine species*:

"The model developed for the shrimp Crangon franciscorum relates the abundance of juveniles with March through May freshwater outflow. Strong positive relationships were found between March through May outflow and both juvenile and the subsequent years mature shrimp." *(p. i)*

"The model developed for longfin smelt is based upon a significant positive relationship between abundance and February through May freshwater outflow." *(p. ii)*

"The model developed for starry flounder was based upon the significant positive relationship between starry flounder abundance and freshwater outflow from March to June." *(p. iii)*

8

Kohlhurst, David W., Stevens, Donald E., and Miller, Lee W., "*A Model for Evaluating the Impacts of Freshwater Outflow and Export on Striped Bass in the Sacramento – San Joaquin Estuary; Entered by the California Department of Fish and Game for the State Water Resources Control Board 1992 Water Rights Phase of the Bay-Delta Estuary Proceedings,*" 1992, month not given. (WRINT-DFG-Exhibit 3)

Research conducted for a model developed by the California Department of Fish and Game showed ***correlation between exports and loss of young-of-year striped bass****:*

'Some might question the biological importance (absent the statistical results form the foregoing analysis) of controlling export losses in all months after the yoy index is set. However, data are available to show the effect of monthly variation in export rate on cumulative annual losses (Figure 12)." *(p. 35)*

For adult striped bass, ***exports must be reduced and outflow increased*** *to improve abundance:*

"These results show that, with average outflows for each year type, exports must be much more restricted to maintain an adult population of 1.7 million than for a population of 600,000." *(p. 39)*

"Results of this sensitivity analysis suggest that changes in April-July outflow have substantially more effect in dry than in wet year types and that changes in fall and winter water export have greater impact on adult striped bass abundance in wet years (Table 16)." *(p. 42)*

9

Kjelson, Martin A., U.S. Fish and Wildlife Service, "*The Needs of Chinook Salmon, Oncorhynchus Tshawytscha, in the Sacramento – San Joaquin Estuary,*" Direct Testimony presented at Water Right/Water Quality Hearing, September 21-23, 1987 (USFWS Exhibit No. 31)

Martin Kjelson, representing the U.S. Fish and Wildlife Service, provides extensive documentation for the 1987 hearings of the relation between flow and juvenile salmonids in the estuary, finding particularly ***strong correlations between flow, water temperature, operation of the Cross Channel Gates and smolt survival*** *on the Sacramento River side of the Delta:*

1) "The abundance of smolts at Chipps Island is positively correlated with flow at Rio Vista." *(p. 3)*
2) "The survival of marked hatchery smolts through the Sacramento Delta between Sacramento and Suisun Bay is positively correlated to flow and negatively correlated to both temperature and the percent of the flow diverted off the Sacramento River through the Delta cross channel and Georgiana Slough at Walnut Grove." *(p. 3)*
3) "Maximum survival was reached at flows of about 30,000 cfs at Rio Vista." *(p. 36)*
4) "Smolt survival is highest when water temperatures [at Rio Vista] are below 66°F." *(p. 4)*
5) "Closing the Cross channel is of considerable benefit to salmon survival at low flows when temperatures are acceptable." *(p. 4)*
6) "Potential measures to improve salmon smolt survival through the Sacramento Delta include: increasing flows, closure or screening of the Delta Cross channel, elimination of reverse flows in the lower San Joaquin and reducing export levels in the southern Delta." *(p. 5)*

Kjelson also documents various relative rates of ***survival of salmon fry*** *in the Delta:*

1) "The survival of fry was greater in the upper Sacramento River than in the Delta." *(p. 7)*
2) "Fry released in the Northern Delta appeared to survive better than fry released in the Central Delta, except in years of very high inflow." *(p. 7)*
3) "Chinook fry that rear in the Delta contribute some portion of Central Valley salmon production with that proportion increasing as runoff increases." *(p. 8)*

Regarding ***adult Chinook migration*** *through the estuary, the author notes:*

"Migrations through the estuary are aided by positive downstream flows of 'homestream water' and temperatures less than 66°F." *(p. 8)*

*In discussing **juvenile rearing upstream of the Delta**, Kjelson observes:*

"The large number of smolts leaving the Delta in 1982 and 1983 could in part be the result of the increased flow upstream during incubation and rearing as noted by Stevens and Miller (1983)." *(p. 30)*

*The Fish and Wildlife Service extensively studied **smolt migration rates** and on the Sacramento side of the watershed. Among the conclusions are:*

1) "We found no relationship between smolt migration rate and the magnitude of flow in either the Sacramento Delta or the Bay." *(p. 32)*
2) "On the average, fall-run smolts pass through the entire Delta and Bay in about two weeks while migration from the upper Sacramento takes about a week." *(p. 32)*

*In terms of **timing of smolts passing through the Delta** and Bay, Kjelson makes the following observations:*

1) "The numbers of fall-run juveniles passing Chipps Island between April and June are highly variable…. About half the fish are seen in May, while the remainder is split equally between April and June." *(p. 18)*
2) "…the San Joaquin outmigration appears earlier. Smolt migration out of the San Joaquin peaks about May 1." *(p. 23)*

10

U.S. Fish and Wildlife Service, "*Abundance and Survival of Juvenile Chinook Salmon in the Sacramento – San Joaquin Estuary*," June 1992. (Exhibit WRINT-USFWS-9)

This document expands on and updates the 1987 report by Kjelson (FWS-31, 1987). It is notable that research for this report included data from a succession of dry years (1987-1991). Among the findings, organized by category were:

In terms of the ***seasonality of migration of smolts*** *through the Delta, the report stated:*

"Since 1985, we have found a smaller percentage of the annual number of outmigrants in June and a greater percent in April. This may be due to the fact the [sic] drier years which account for 6 out of the last 7 years, cause fish to grow faster and thus migrate out sooner, or perhaps the fish that historically migrated are having high mortality and thus have been genetically removed from the population." *(pp. 20-21)*

The report noted that ***hatcheries*** *and hatchery management changes had affected the escapement salmon returns. The* ***rates of migration by hatchery and wild fish*** *were also compared. The results suggest that a general use of hatchery fish in experiments may paint an overly optimistic picture of the condition of the wild salmon fisheries:*

"It is important to note that releasing hatchery fish downstream of the Delta since the early 80's has allowed escapement back to the American and Feather Rivers to be relatively stable over time." *(p. 22)*

"In the four years that we have measured the migration rate of Coleman hatchery and "natural" fish in the North Delta, we have found that the hatchery fish tend to migrate substantially faster than the "natural" fish. … Generally, more of the fish released from the hatchery are of smolt size and actively migrate whereas the "natural" fish may be somewhat smaller and their migration slower." *(p. 26)*

The importance of the ***Cross Channel Gates and Georgiana Slough as hazards*** *to migrating salmon was confirmed:*

To date, we have determined that fish diverted off their main migration path into the Delta cross channel and Georgiana Slough have much higher mortality than those allowed to migrate down the main Sacramento River. Coded wire tagged fish released above the cross channel and Georgiana Slough with the cross channel gates open survived about twice that of those released with the gates closed (Tables 11 and 12). We found similar difference using both our trawl (3.4 to 1.6) and ocean (2.2 to 1.2) index of survival.

In addition, the difference in survival of fish released above versus below the Cross Channel with the gates closed, is due to the diversion impact of Georgiana Slough alone. The difference between being diverted into Georgiana versus being allowed to stay in the main channel, is greatest using our trawl estimate (1 to 1.6) but is confirmed with the ocean index (1 to 1.2).

(p. 40)

Both our trawl and ocean data supports our previous conclusions that their [sic] would be substantial benefits to migrating Sacramento salmon smolts if both the cross channel and Georgiana Slough were closed. This is a potential structural method for increasing salmon smolt survival through the Delta. *(p. 44)*

While patterns on the San Joaquin side were less consistent than on the Sacramento, the report was unequivocal in pointing out the ***loss of juvenile salmon between Stockton and the mouth of the Mokelumne****:*

The survival rate on a per mile basis was the greatest between the Lower Mokelumne site and Jersey Point and was 17 times greater than that between Stockton and the Lower Mokelumne release site. This analyses [sic] demonstrates that the greatest mortality in the South Delta in 1991 was on the main San Joaquin River between Stockton and where the Lower Mokelumne enters the San Joaquin. This mortality is even greater than that experienced between Dos Reis and Stockton.

It is not surprising that the reach between Stockton and the Lower Mokelumne junction has the greatest mortality, considering that in that reach the number of diversion channels off the main channel taking water south to the pumps is greater than in other areas. Once the fish are diverted towards the pumping plants their migration is delayed and they are exposed to potentially greater temperatures, high in channel and Clifton Court predation and direct impacts of the pumping plants. This analyses [sic] suggests that one salmon smolts reach the Lower Mokelumne Junction mortality is significantly reduced.

(p.61)

In both months [April and May] it is clear that the vast majority of mortality is associated with the area between Stockton and the Lower Mokelumne junction and that during times of higher pumping survival through that area is much less. *(p. 66)*

Although our data infers that the installation of a barrier will likely improve smolt survival through the San Joaquin Delta, it is imperative to recognize that a barrier alone most likely will not be a panacea to the mortality problems for smolts migrating down the San Joaquin. As we documented in 1991, significant smolt mortality occurs downstream of the proposed barrier. Additional measures such as increased flows and decreased exports also are needed to ensure adequate survival through the San Joaquin Delta system. *(p. 75)*