MAY 16 1994

COMMENTS OF THE DEPARTMENT OF WATER RESOURCES AT THE SECOND PUBLIC WORKSHOP FOR THE REVIEW OF STANDARDS FOR THE SAN FRANCISCO BAY/ SACRAMENTO-SAN JOAQUIN DELTA ESTUARY[1]

1. What are the principal ESA issues the SWRCB should consider during this review?

Much has been said recently about the need for an "ecosystem" and "multispecies" approach to the Delta, especially in reaction to the rigid, single-purpose approaches of the federal ESA and CWA. The ESA limits its focus to the needs of single species in the estuary, and the CWA only considers the influence of water quality factors on beneficial uses.

Interestingly, the Board's traditional approach to Delta regulation has been, in fact, a system-wide, multi-species and multi-use perspective. Under the Water Code and the California Constitution, the needs of all species and all uses are within the Board's purview and charge.

Thus a difficult situation arises in considering how the Board should deal with the superseding federal regulation of listed species in a manner which does not simply turn a deaf ear to the other biological and water use needs of the estuary.

It seems to us that, whatever the Board does in terms of State standards, a guiding principle should be to preserve as much

[1]Presented by David B. Anderson, May 16, 1994

flexibility as possible to water users subject to federal ESA regulation.

What are the choices, then, for the Board?

1. The Board adopts NMFS and USFWS ESA requirements as State standards. This option is extremely undesirable, for three reasons. One, it constitutes double regulation, two sets of regulatory hoops for a single regulatory purpose. If the Board standards and ESA requirements agree, then the Board's are superfluous; and if the ESA's requirements change and disagree with the Board's, then the result is a confusing and vexatious contradiction.

   Two, ESA requirements are not the product of balancing, do not reflect all the public interest concerns in the estuary, and do not therefore conform to the requirements of state standards. Three, the burdens placed upon state water uses and allocation by the ESA should remain clear, and should not be confused by imitative State "requirements".

2. The Board adopts specific standards for ESA species without reference to the federal requirements. This alternative also suffers from the problem of double and possibly contradictory regulation.

3. The Board does not adopt specific standards for listed species. This alternative actually provides the greatest flexibility by allowing the regulated parties to deal with a single regulation, NMFS or USFWS. That

flexibility, however small, found in the ESA consultation process, should not be confused or lost by duplicative requirements or approvals needed from the Board in order to fashion alternatives or to react to urgent circumstances.

The Board might to able to develop balanced, multi-species standards that also provide umbrella protection for ESA species. Board standards could possibly be based on a broad "allocation" of late-winter/spring water to "aquatic resources" including listed species. If federal ESA requirements were later to increase, then the Board would be required to re-balance to avoid an increased burden on off-stream uses, i.e., non-ESA aquatic resources would be cut back. Perhaps the mechanism for adjustment could be built into the standards as automatic shifts in other spring standards if ESA requirements increase. All practical options should be looked at. Hopefully, the great discretion ESA agencies truly have, given the enormous scientific uncertainties with which they deal, can be exercised to operate within reasonable multi-species and system-wide State standards.

In summary, the essential points are that federal ESA requirements must be recognized and dealt with <u>as such</u>; and that Board action should not deprive water users that modicum of flexibility that the federal act permits.

Although this topic is to be directly raised at the June workshop, it is also important to say at this time that the Board's standard-setting should be placed in the context of the broader management needs for the estuary. These needs and proposals to address them, while not necessarily within the Board's regulatory jurisdiction, should be aggressively identified and set forth by the Board.

The Department's detailed answers to the next two questions, on Delta diversions and analytic methods, are attached. One point on diversions merits special emphasis. On April 27, we noted as we have often done before, that outflow is at times recommended to address or solve problems which may have non-outflow or non-water-costing solutions; and that it is essential for the Board to look for those solutions. The impacts of Delta diversions are such a problem. Given the interim nature of the standards to result from these proceedings, the Board may be inclined as a practical matter to set outflow standards for those problems. If you do, you should expressly recognize that later, diversion-specific solutions may obviate or lessen the need for the flow standards that you set.

DWR - ATTACHMENT 1

2. <u>What are the effects of diversions throughout the Bay-Delta Estuary on beneficial uses?</u>

Agricultural Diversions

Larval, juvenile, and adult fish are vulnerable to entrainment into Delta agricultural diversions, a potential risk for the populations. An estimated monthly average of 2,000 to 5,000 cubic feet per second is diverted during the peak irrigation period (April-August) from about 1,800 diversions scattered throughout the Delta (Brown 1982). This is the same order of magnitude as is exported by the SWP and CVP in the southern Delta. This peak period coincides with months when large numbers of young Chinook salmon, striped bass, American shad, Delta smelt, and other fish species are present in the system. Little is known about the extent of entrainment losses to agricultural diversions or the factors affecting losses. Entrainment losses to agricultural diversions in the Delta may be a substantial source of mortality for the early life stages of some Delta fish species.

In the Sacramento-San Joaquin Delta, two general types of agricultural diversions are used, siphons or pumps, depending on the elevation of the land under irrigation. Siphons are common on Delta islands and low lying adjoining tracts. Pumps are more common in outlying Delta areas with higher land surface elevations. Most commonly, siphons are 10-18 inches in diameter (range: 6-66 inches), and pump intakes are 6-16 inches in diameter (range: 6-54 inches) (California Department of Water Resources, unpublished data). Intakes are unscreened and draw water from 2-3 feet above the channel bottom, but position may vary due to changing bottom conditions or other causes. Diversions are usually not metered so exact diversion volumes are unknown. Water is siphoned or pumped from the Delta channel, applied to fields by a system of ditches, and drainage returns are pumped back into the channel. Operations vary with the type of crop under cultivation, which may change seasonally or yearly.

The Delta Agricultural Diversion Evaluation was implemented by the Department of Water Resources in 1992 to assess the extent to which various fish species, including delta smelt, are lost to these diversions (Spaar, in press). Sampling was conducted from April through October, 1992, in diversions and adjacent channels mainly for eggs and larvae, with some sampling for juveniles and older fish. Results indicate that chameleon goby, threadfin shad, and centrarchids (basses, crappies, sunfish) were the most abundant larval species entrained by the diversions, which could be due to their preference for spawning or rearing in shallow water, edge-type habitat with cover. The vulnerability of eggs and larval fish to entrainment tends to vary between species and appears to depend on seasonal occurrence, abundance, and distribution of a species in the adjacent Delta channel and on operations of the diversion (seasonal timing, frequency and duration, and flow and volume). Larval threadfin shad at McDonald Tract were more susceptible to entrainment than channel density indicated. Density in the diversion was significantly higher than channel. Larvae of threadfin shad (other sites), centrarchids, minnows, and logperch were as susceptible to entrainment as channel density indicated. Threadfin shad (2 sites) and centrarchid (all sites) diversion densities were not significantly different from channel densities, and no difference was found for minnows and logperch at Bacon Island. Chameleon goby, striped bass and prickly sculpin larvae were less vulnerable to diversions than channel density indicated. Diversion density was significantly lower than channel density for these species at Bacon Island, and for chameleon goby at other sites. However, Allen (1975) found that concentrations of striped bass larvae in Sherman Island diversions did not vary statistically and were of the same general magnitude as those in the adjacent San Joaquin River.

Larval fish were the predominate lifestage entrained and appear to be the most vulnerable to these diversions. Generally, they are usually more abundant than juveniles or older fish due simply to the impact of mortality on a population before they can reach these later stages. Larvae are also poor swimmers, and if in the proximity of an intake, would probably be unable to avoid entrainment. The species collected in the agricultural diversions were usually a subset of the larval species present in the adjacent channel areas.

Based on findings of the 1992 pilot study, entrainment appears to depend largely on the species in question, its lifestage, seasonal abundance and distribution in the adjacent channel (including location in the water column), and operations of the diversion (seasonal timing, frequency and duration, and flow and volume) (Spaar, in press). Many diversions do not operate continuously and only divert water over shorter periods of a few days to a few weeks. Seasonal timing of diversions is important in that high volumes of diversions may coincide with periods of high abundance of egg and larval stages resulting in high entrainment. For example, Bacon Island had high diversion volumes in late April though mid-June, when striped bass larvae were present and abundant. The impact of diversions would be lower later in the season, when fish are larger and less vulnerable to entrainment.

Estimated Entrainment of Eggs and Larvae: Total larval entrainment at Bacon Island was highest for threadfin shad, chameleon goby, striped bass, and logperch. In 1992, threadfin shad (696,278 larvae) were entrained from mid-May to early September, with highest losses in early August. Entrainment of chameleon gobies (635,606 larvae) stretched from late April to mid-September 1992 with the bulk of the losses in May and June. Striped bass (197,487 larvae) were entrained from the start of diversion in mid-April until early June. In 1993, threadfin shad (3,498,052 larvae) were entrained from early May to the end of sampling in mid-July. Striped bass (228,386 larvae) and logperch (231,341 larvae) were entrained from late April and early May to mid-June. At the Naglee Burk site, total entrainment was highest for threadfin shad (1992: 917,885 and 1993: 1,313,286 larvae) and chameleon goby (1992: 385,046 and 1993: 152,003 larvae) in 1992 and 1993, and also high for centrarchids (103,105 larvae) in 1993. The bulk of the entrainment occurred in May through mid-June in both years.

In 1992, striped bass larvae were entrained only at the Bacon Island site from April 20 to June 9, 1992. Total entrainment was 197,487 larvae. In comparison, total entrainment was one to two magnitudes higher at the SWP and CVP in 1992 (7,948,000 and 11,271,000 larvae, respectively) (Spaar 1993). It would require approximately 100 agricultural diversions of similar volume and operations as the Bacon Island siphon, and in an area of similar striped bass densities, to equal the magnitude of losses at the SWP or CVP. With approximately 1800 Delta diversions, there is a likelihood of at least 100 diversions being similar.

Estimated Entrainment of Juvenile and Older Fish: Entrainment of juvenile and older fish could not be estimated for the Bacon Island site in 1992. The initial sampling method using a fyke-type net with wings proved to be totally unreliable for estimating diversion of fish. Late in the 1992 season a fyke-type net was used to cover the mouth of the siphon and sample the total diversion flow. No fish were caught with this net from late September through October 1992.

Improvements in sampling methods and gear for 1993 has resulted in reliable, quantitative catch data for this site. About 13 species were collected from the diversion in comparison to about nine species from channel sampling with a tow-net and trawls (midwater, otter). Striped bass and threadfin shad were the most abundant species caught in the diversion. Yellowfin goby, chameleon goby, logperch, and prickly sculpin were moderately low in abundance. Juvenile delta smelt were collected on May 17, 20, and 27, 1993. Their sizes ranged from 15-16 mm TL on May 17 to 23 and 26 mm TL on May 20 and 27. In Middle River, threadfin shad were the most abundant fish caught. American shad and channel catfish were also abundant, but were not collected from the diversion. Striped bass were moderately abundant in the channel catches. No longfin smelt or splittail were collected from the diversion or channel.

Entrainment losses for 1993 were estimated from mid-April to mid-October essentially spanning the entire diversion season. The fish entrained were mostly small juveniles less than about 30-40 mm in length. Estimated entrainment was highest for striped bass (19,116 fish) and threadfin shad (11,593), and moderate for chameleon goby (2,639 fish). Entrainment of delta smelt was very low (5 fish).

Fewer species are generally caught at the Naglee Burk site than at Bacon Island. The juvenile catch from August through October 1992 totaled only 24 fish and 5 species. In June to October sampling for 1993, the total number of fish caught increased to 3,975 fish and 10 species, most likely to the addition of overnight sampling and increased fishing effort. Threadfin shad predominated at this site. White catfish were also common in the collections and usually exhibited some type of body damage due to the intake.

Entrainment losses were estimated for all juvenile and older fish caught at the Naglee Burk site in 1992 and 1993. In 1992, chameleon goby (555 fish) and bluegill (341 fish) had the highest estimated losses. Losses for white catfish (182 fish) and threadfin shad (127 fish) were moderate. These fish were mainly juveniles about 20-90 mm in size. In 1993, threadfin shad entrainment was high (38,081 fish) and entrainment of centrarchids (bluegill, largemouth bass, black crappie)(113 fish) and catfish (white, blue, channel; brown bullhead)(844 fish) were moderately low in comparison.

Delta Smelt: A detailed discussion of local agricultural diversions was presented in the 1993 Delta Smelt Biological Assessment. Diversions in the northern and central Delta, where smelt abundances are highest, are likely the greatest problem. During 1992 sampling, no larval, juvenile, or adult delta smelt were collected from the four diversions sampled (Spaar, in press). In this pilot year, however, sampling methods for juvenile and older fish were found to be inefficient. In addition, the Twitchell Island diversion off the San Joaquin River, an area of known delta smelt abundance, could not be sampled.

Larval smelt were collected in April and May by egg and larval sampling in the Delta channels adjacent to the Twitchell Island, Bacon Island, and McDonald Island sites. Larval abundance in these catches was generally low, and catches were infrequent in comparison to most other larval species caught, such as chameleon goby, threadfin shad, and striped bass. No larval smelt were collected near the Naglee Burk site in the southern Delta.

Sampling methodology and juvenile nets were modified for 1993 to increase sampling efficiency. During 1993 sampling, no larval delta smelt were collected from the diversions using egg and larval methods (DWR, unpublished data). Larval delta smelt were collected before and during the diversion season by egg and larval sampling in the Delta channels adjacent to the Twitchell and Bacon Island sites (central Delta). Diversions at these sample sites started later in 1993 than in 1992 due to the heavy rainfall from fall 1992 through spring 1993, which delayed the onset of irrigation diversions (late April at Bacon and late May at Naglee Burk). Delta smelt larvae were present from March 19 to April 10 (14 larvae total, range 5.0-7.0 mm total length) in the San Joaquin River off Twitchell Island and again on June 7 and 17 (2 larvae, range 10.5-20 mm TL). Larvae were collected on March 23 and 31 and June 9 (4 larvae total, range 5.5-7.4 mm TL) in Middle River off the Bacon Island site.

Preliminary data are also available for 1993 from the juvenile net (1/8-inch mesh with live-box) (DWR, unpublished data; Griffin 1993). Results indicate no delta smelt were caught at the Naglee Burk and McMullin Tract sites (southern Delta), or at Twitchell or Bouldin Islands (central Delta). However, juvenile delta smelt were collected from the Bacon Island diversion site (central Delta) on May 17 (range 15-16 mmTL), 20 (23 mm TL) and 27 (26 mm TL), 1993.

In general, delta smelt are probably most vulnerable to entrainment from February through June, during their larval and early juvenile stages. Swimming ability is weakest in the larval stage for most fish species. The irrigation season runs generally from late March or early April through September (Brown 1982), but varies from year to year depending on weather, crop, and other factors. Diversions are minimal or nil during December through February. Winter irrigation is usually for winter wheat or other grains, and in a drought year, for permanent crops (orchards, vineyards). The agricultural diversions now being studied often do not begin operations until late April or May. Some diversions are often operated intermittently during the diversion season. Four of the five sample sites monitored in 1993 diverted intermittently, including all irrigation diversions for Bouldin Island. Potentially, the period of highest losses of delta smelt to agricultural diversions would be April through June, based on life stages at this time and timing of the irrigation season.

Splittail: Some information is available on splittail from 1992 and 1993 sampling for the Delta Agricultural Diversion Evaluation. No larval, juvenile or adult splittail have been collected from any of the diversion sites. No juvenile or adult splittail were collected using a townet sled in adjacent channels in 1992 and 1993 or by otter or midwater trawl in August and September 1993 (Spaar, in press; DWR unpublished data).

Larvae were collected in egg and larval sampling in the adjacent Delta channel in both years at two sites - Twitchell Island and Naglee Burk. In 1992, one larvae (7.6 mm TL) was caught off the Twitchell Island site (San Joaquin River) on April 16, and downstream of the Naglee Burk site (Old River) on April 4 (1 larvae, 6.8 mm TL) and 8 (2 larvae, 7.0, 7.1 mm TL). In 1993, splittail larvae were again only collected in the channel adjacent to these two sites. Splittail larvae were caught consistently from March 23 to April 10, 1993, off the Twitchell Island site (Total of 5 larvae, ~ 8 mm TL). One larvae was caught on April 6, 1993, downstream of the Naglee Burk site.

In general, splittail are probably most vulnerable to entrainment from February through June, during their larval and early juvenile stages. Swimming ability is weakest in the larval stage for most fish species. The irrigation season runs generally from late March or early April through September (see discussion in delta smelt section). Potentially, the period of highest losses of splittail to agricultural diversions would be April through June, based on their life stages at this time and timing of the irrigation season .

Problems Encountered: The ability to obtain information on entrainment of fish to agricultural diversions can be difficult. There is a reluctance on the part of farmers and irrigation districts to provide access to siphons or pumps for sampling. Even if access is obtained, there are some communication problems between the department attempting to sample a diversion and the diverter. There may be little or no notification about when diversions are to start or end. Since many diversions run intermittently and may be completely shut down or continue to divert for several days at a time, it is difficult to determine the irrigation schedule or the duration of the pumping. There are also sampling problems that can make the collection of information difficult. Generally, diversions tend to be similar for a given island or area, but each may present its own set of unique sampling problems depending on the configuration of the outfall and irrigation channel. Also, debris load varies from site to site and throughout the season which may cause problems with the samples and the gear itself.

PG&E DIVERSIONS

Pacific Gas and Electric Company operates two power generation facilities, Contra Costa Power Plant and Pittsburg Power Plant within the range of delta smelt. The Contra Costa Power Plant is located approximately 6 miles east of the confluence of the Sacramento and San Joaquin Rivers. Pittsburg Power Plant is situated on the south shore of Suisun Bay in the town of Pittsburg. Each power plant is composed of seven generating units that rely on water diverted from the lower San Joaquin River and Suisun Bay for condenser cooling. Cooling water is diverted at a rate of up to approximately 1,500 and 1,600 cfs for Contra Costa Power Plant and Pittsburg Power Plant, respectively, forming a thermal plume as it is discharged back into the estuary. However, pumping rates are often significantly lower under normal operation. The intakes at all units at both power plants employ a screening system to remove debris, but these screens allow entrainment of fish smaller than approximately 38 mm.

PG&E is presently in the process of an Endangered Species Act consultation with U.S. Fish and Wildlife to address impacts to local fisheries. A draft Habitat Conservation Plan has been prepared, but is not available for public review. The limited information for two major species of concern, delta smelt and splittail is summarized below.

Delta Smelt Entrainment: Direct entrainment and occurrence of delta smelt near the power plants is poorly understood because of taxonomic problems with earlier studies. Young delta smelt and longfin smelt are difficult to differentiate, so much of the early data is at the family (Osmeridae) level only. The available information suggests that larval and juvenile smelt, including delta smelt and longfin smelt, were historically one of the most abundant fish taxa in the area. In 1978 and 1979, Osmeridae were the most common group collected in ichthyoplankton samples near Pittsburgh Power Plant and the third most abundant near Contra Costa Power Plant (Ecological Analysts 1981a, 1981b).

There is also some specific evidence that juvenile and adult delta smelt have persisted in the project areas. Fishery surveys using a combination of gear types found that delta smelt comprised 1.8 percent of the catch of all species near Pittsburg Power Plant from August 1978-July 1979 (Ecological Analysts 1981c) as compared to 1.1 percent at discharge and reference sites in from July 1991 to June 1992 (PG&E 1992a). Studies near Contra Costa Power Plant reported that delta smelt constituted only 0.1 percent of the catch in 1978-1979 (Ecological Analysts 1981d), but 0.7 percent in 1991-1992 (PG&E 1992a). However, results from the summer townet survey at stations closest to Pittsburgh Power Plant indicate that abundance has declined since the peak levels in the mid-1970s. The mean catch of delta smelt declined in the 1980s at townet stations 520 and 508, located upstream and downstream of Pittsburg Power Plant, respectively. At station 804, a site near Contra Costa Power Plant, mean catch of delta smelt has been consistently low except for 1965 and 1973-1977 (DWR/USBR 1993).

PG&E entrainment monitoring has conducted extensive monitoring studies at both power plants. Early studies were general in nature, followed by later emphasis on larval and juvenile striped bass. Entrainment estimates for smelt are available from 1978 and 1979 only and the larval data is limited because of difficulties in differentiating longfin and delta smelt. PG&E (1981a, 1981b) reports that from April 1978 to August 1979, more than 50 million smelt larvae (Osmeridae) were entrained at Pittsburg Power Plant with an additional 11,000 juvenile delta smelt impinged on the screens. Entrainment was similarly high at Contra Costa Power Plant for Osmeridae larvae (16 million) and juvenile delta smelt (6,400). An important consideration in evaluating these data is that larvae entrained in cooling systems are not necessarily lost. High survival rates of entrained striped bass and other species have been observed, but the effects on delta smelt are not known.

Based on survey results from nearby summer townet stations, there is evidence that many of the larvae entrained in the 1978-1979 studies were delta smelt (DWR/USBR 1993). Longfin smelt are rarely caught near Contra Costa Power Plant and were not observed in 1978 and 1979. This compares to low but detectable levels of delta smelt. Delta smelt also outnumbered longfin smelt during 1978 and 1979 near Pittsburgh Power Plant. A limitation in the interpretation of these results is that the summer townet survey was conducted after the period of peak entrainment, so the species composition may not be strictly comparable.

Thermal effects may result in direct mortality, behavioral attraction, avoidance or blockage or increased predation. This issue is discussed in detail in a recent report by PG&E (1992b). The study found greater numbers of some fish species near thermal discharge sites, but no evidence for direct mortality of striped bass and no thermal blockage of migratory species including Chinook salmon, striped bass or American shad. Insufficient numbers of delta smelt were collected to draw any conclusions about how they are affected by the thermal discharges. Predation on juvenile chinook salmon and larval striped bass from thermal stress may be higher in Contra Costa Units 6 and 7 discharge canal, but the report concluded the effect is probably minimal. The overall effect of thermal discharges on delta smelt are not known, but sampling indicates that there is no behavioral attraction

PG&E has implemented a resource management program to reduce striped bass loss since the 1978-1979 studies were completed. During the period of peak striped bass entrainment (May - mid-July), power generation units are currently operated preferentially using fish monitoring data. This program has successfully reduced entrainment losses of larval and juvenile striped bass by over 75 percent in recent years (PG&E 1992a). The effect of new operations may have incidental benefits to delta smelt, but cannot be estimated because there is presently no monitoring requirement for this species.

Splittail Entrainment: Adult and juvenile Sacramento splittail are commonly found in the vicinity of PG&E facilities in the estuary (PG&E 1992a). There is some evidence that splittail are attracted to thermal discharge, as indicated by higher abundance within the Pittsburg Power Plant thermal plumes (Gritz 1971). However, entrainment of splittail appears to occur at a much lower level than for delta smelt. Results from April 1978 - April 1979 report that 123,000 splittail were entrained at Contra Costa Power Plant (Ecological Analysts 1981a, 1981b). More recent data is not available.

3. What methods should the SWRCB use to analyze the water supply and environmental effects of alternative standards?

CVP-SWP SYSTEM SIMULATION MODEL (DWRSIM)

The Department of Water Resources Planning Simulation Model, DWRSIM, is a generalized computer simulation model designed to simulate the operation of the Central Valley Project and the State Water Project system of reservoirs and conveyance facilities. Except for New Melones Reservoir and the Stanislaus River, the San Joaquin River system and tributary reservoir operations are treated as pre-modeled inputs to DWRSIM and are not operated to meet flow or quality requirements in the Delta. The model provides for proper sharing of Sacramento River and San Joaquin River Delta inflows between the CVP and SWP according to the Coordinated Operations Agreement. Studies are conducted with DWRSIM on a monthly time basis, utilizing the historical 71-year hydrologic sequence of flows from water years 1922 through 1992 as input. However, the 71 years of monthly historical flows are adjusted to reflect the effect of estimated 1995 level land use patterns and current operations of local upstream reservoirs. Thus, when an operations study is performed at the 1995 level, the model simulation results show how the entire system would perform while meeting project demands whenever possible, assuming the historical 71-year sequence of hydrology (1922-1992) were to recur at 1995 level of development.

The simulation of the CVP-SWP system is very detailed and complex. The model accounts for system operational objectives, physical constraints, and legal and institutional agreements or statutes. These parameters include requirements for flood control storage, instream flows for fish and navigation, allocation of storage among system reservoirs, hydropower, pumping plant capacities and limitations, and required minimum Delta operations to meet water quality and Delta outflow objectives. A more detailed description of the DWRSIM model as well as the operations criteria used in these studies is available in several documents available at DWR.

DWRSIM was previously modified to analyze a number of alternatives related to Draft D-1630. In addition, various features have been added during the last year to analyze National Marine Fisheries Service Winter Run criteria, U. S. Fish & Wildlife Service Delta Smelt criteria and the Environmental Protection Agency's proposed estuarine standard X2. Recent changes and refinements to DWRSIM which have been incorporated and are proposed for use henceforth are as follows:

1. The 1995 hydrology data base (present level) for water years 1922 through 1992 has been updated to reflect the latest land use estimates consistent with Bulletin 160-93. Future level hydrologies are also available for years 2000, 2010 and 2020.

2. The model has been refined to allow several options to share CVP/SWP reduced pumping at Tracy and Banks Pumping Plants when reverse flow criteria (QWEST) limits Delta exports. This also allows curtailing Delta exports at different levels as a function of storage in conservation reservoirs.

3. The model now has the capability to meet any proposed salinity criteria (e.g. 2 ppt salinity line, X2) at key locations in the western Delta. (Note: currently the model uses the X2-outflow relationship proposed by Monismith et. al.).

4. Automatic reduction of SWP and/or CVP south of Delta deliveries is provided if springtime operational constraints or export limits on Tracy and Banks Pumping Plants restrict the annual allocation of deliveries which would be available based on upstream supply conditions.

5. The model has also been modified, as an option, to apply deficiencies to SWP contractors as measured from Table A contractual entitlements. This affects the split in

deliveries between SWP agricultural and urban contractors.

6. The MDO model which computes minimum required Delta outflow to meet any set of Delta standards has been merged with DWRSIM. This process has removed the discrepancy of not using identical Delta consumptive use values.

7. For 1995 level studies, the current interim criteria for Folsom Lake flood control operations incorporates the flexible criteria per "Folsom Dam and Lake Operation Evaluation" provided by Sacramento District Corps of Engineers dated December, 1993 to provide 100-year flood protection to the downstream area.

8. The Hydrologic Engineering Center Data Storage System (HECDSS) has been adapted to manage input and output data for DWRSIM model studies. The HECDSS system enables efficient storage and retrieval of hydrologic time-series data; DSS utility programs also include a powerful graphics program.

9. The Stanislaus River System Model (STANSIM) has been integrated with DWRSIM. Users will now be able to simulate Vernalis standards by providing required criteria as input to DWRSIM.

10. Simulation of the CVP Delta Mendota Canal has been expanded. In addition, an option has been added to allow use of unused capacity in the joint reach portion of the California Aqueduct by either project.

11. A variable Delta export demand option is now available for use in present (1995) level studies. CVP and SWP demands south of the Delta may be adjusted to account for wetter conditions (based on Central and Southern California indices).

Despite its many features, DWRSIM has a number of limitations which require that caution be exercised when analyzing or interpreting model results. Many of these limitations are due to lack of information or objective criteria and would be a limitation of any model envisioned. These limitations are discussed below:

1. DWRSIM primarily simulates the CVP/SWP system of reservoirs and conveyance facilities. Therefore, when analyzing water supply impacts of proposed new Delta operations criteria, the SVP/SWP system is used as a

surrogate to estimate water supply impacts.

Actual responsibility or water supply impacts might be allocated to other Delta water users as well. It will be necessary to establish operations criteria for "non-project" users before more detailed modeling could proceed.

2. DWRSIM is a monthly model. A number of proposed new Delta standards such as EPA's proposed X2 standards or mid-month export curtailments are based on time increments of less than one month. Thus, assumptions are used in order to approximate water supply impacts of these criteria.

3. Endangered Species Act limitations on Delta export pumping based on actual "fish take" cannot be readily modeled in DWRSIM. Assumptions for these limitations based on operational experience during the past two years may be incorporated if desired.

4. Methodology to share the impacts of newly imposed ESA requirements or other proposed standards between the CVP and SWP (i.e. effect on the Coordinated Operations Agreement) is unknown. Various assumptions are possible with DWRSIM and may be specified by those requesting studies. This sharing will effect relative reservoir levels and available water for delivery between the CVP and SWP. Keep in mind, however, that allocation of responsibility for meeting proposed standards by other Delta water users will also change CVP and SWP delivery capabilities and reservoir operations.

5. The CVPIA mandates that 600,000 to 800,000 acre feet of CVP yield be allocated annually for environmental purposes. However, the Bureau has not yet established specific criteria on how this obligation will change CVP operations or how much additional Delta inflow or outflow this will provide. Until such criteria are established, interpretation of modeling results are subject to the uncertainty of the CVPIA allocation.

6. At present, deficiencies to all CVP contractors are preset based on Shasta criteria, with additional deficiencies applied, when necessary, in DWRSIM to south of Delta contractors to achieve desired CVP operations. DWR is presently working on changes to DWRSIM to dynamically determine deficiencies to all CVP contractors which will provide considerable flexibility in this area. However, the Bureau has not yet developed specific criteria or deficiency rules for new ESA and

CVPIA requirements that can be modeled.

Despite the limitations listed above, DWR feels that DWRSIM is an extremely powerful tool for analyzing proposed changes in criteria associated with Delta and other instream operational constraints. Special requests or needed changes requested by the SWRCB will be accommodated to the extent possible.

Further, it should be recognized that the DWRSIM and other DWR models are undergoing constant refinements and we are actively working at incorporation of a number of modeling features or enhancements. Those features which we hope to have in place by the end of 1994 are listed below. Other features are envisioned as part of a long range program.

- A generic procedure to apply deficiencies to all CVP and SWP contractors based on prescribed deficiency criteria. The procedure will be flexible to allow various options when surface water deliveries are reduced.

- Incorporate the Yuba River System as a dynamic operation in DWRSIM.

- The Sacramento-San Joaquin River Delta routine will be expanded to simulate various Delta transfer options and Delta island storage.

- Change the procedure for simulation of CVP and SWP contractor deliveries based on allocation decisions as carried out in real time based on reservoir conditions and water supply forecasts.

- An option will be provided to simulate refuge water operations both in the Sacramento River and San Joaquin River basins.

- A capability to model various types of conjunctive use programs throughout Central Valley will be provided.

- Simulation of water transfers among various types of users and among contractors will be provided.

There are several models that are used to provide data or input support for DWRSIM. The approach used by DWR is to estimate Central Valley water supplies that would be available during the water years 1922 through 1992 at present or future levels of development. Historical records are adjusted based on the Consumptive Use model, the Depletion Analysis model and a "Comp" model to develop and aggregate data for use as input to DWRSIM. The models have been recently modified so that land use changes for multiple studies may be readily incorporated. Although the methodology used in the Depletion Analysis model accounts for use of ground water, ground water itself is not physically modeled.

Additionally, DWR utilizes three separate application models of HEC-3 to simulate upstream reservoir operations on the American River, Yuba River and Bear River. Output from these models is also used to provide input to DWRSIM.

OTHER OPERATIONS MODELS

There are a number of Central Valley operations models which have been developed by DWR and others that may be of interest to the SWRCB.

CVGSM (Central Valley Ground Water Surface Water Simulation Model)

CVGSM is a specific application of IGSM (Integrated Ground Water Surface Water Model) to the Central Valley of California. The IGSM is a generic comprehensive basin planning model which includes routines for groundwater, surface water, ground water quality, and reservoir simulation. The ground water portion is a quasi three dimensional finite element model capable of simulating several layers. The surface water portion includes hydrologic basin analysis for rainfall percolation, run-off, and evapotranspiration. Stream flow simulation operates on a mass balance system. To integrate the surface water and ground water simulation, a soil moisture accounting and unsaturated flow system has been incorporated. The reservoir operations module is included to derive reservoir releases for stream flow accounting. The simulation time step is monthly. Surface water simulation including streamflow estimation can be performed on either a daily or a monthly basis. Water quality simulation is included to track a "plume" through the processes of advection, dispersion, and dissolution. The water quality and reservoir simulation options have not been applied to the CVGSM. The model was developed by Montgomery-Watson and Boyle Engineering in August 1990.

Advantages:

- Encompasses more of the hydrologic system components than other models.
- Modular and easy to modify.

- Input data requirements are well documented.
- Calculates water demands.
- Output data comprehensive.
- Numerous applications.

Disadvantages:

- Input data intensive.
- Does not simulate subsidence.
- Reservoir simulation not comprehensive.
- Requires calibration and verification.
- Resolution of elements is 16 square miles.
- Past ground water usage may not reflect future ground water usage under various system constraints.

Limitations:

- Monthly simulation.

CARS (CVGSM Applied to the American River Study)

CARS is an application of IGSM to the San Joaquin County portion of the study area. It was developed by DWR Central District and the Division of Planning in September, 1993.

Advantages:

- Calibrated and verified.

Disadvantages:

- Data intensive.

Limitations:

- Resolution of the finite element grid is about a square mile.

MASC (MODFLO Applied to San Joaquin County)

MASC is an application of the USGS model MODFLO to the eastern portion of San Joaquin County and was developed by DWR Division of Planning in 1989.

Advantages:

- Calibrated and verified.

Disadvantages:

- Pre-processors are cumbersome to use.
- Post-processors are very detailed.

SANJASM (San Joaquin Area Simulation Model)

A reservoir operation and conveyance system model to simulate the surface water operations in the San Joaquin River and its eastside tributaries. Originally developed by Water Resources Management, Inc. in 1990 (though not yet used). Currently being updated and modified by the Bureau.

Advantages:

- Models the San Joaquin River system from the Consumnes River in the north to the San Joaquin River in the south.

Disadvantages:

- Operational at the 1990 level but not independently verified.

New Flow-Water Quality Relationship on the San Joaquin River

Bureau of Reclamation staff have developed a new flow-quality relationships to model the impact of the west side return flows on water quality in San Joaquin River (part of continuing SANJASM development). Complete details are not yet available to DWR staff. Developed by Bureau staff in April, 1994.

PROJECT SIMULATION MODEL (PROSIM)

Similar to DWRSIM, PROSIM model developed by the U. S. Bureau of Reclamation is also a planning model designed to simulate the operation of CVP and SWP system. PROSIM simulates the operation of CVP and SWP system with current facilities and policies including COA. Essentially, model is intended to carry out planning studies like DWRSIM. DWR is still in the process of analyzing advantages, disadvantages and limitations of PROSIM.

DELTA MODELS

DWR has developed several dynamic models specifically for the Sacramento-San Joaquin Delta.

DWR DELTA SIMULATION MODEL (DWRDSM)

A mathematical model has been developed to simulate the hydrodynamics and water quality within the Sacramento-San Joaquin Delta. The model was previously described in DWR's exhibit WRINT DWR-134A. Four variables are of major interest to mathematical models for the Sacramento-San Joaquin Delta. They are flows, stages, velocities and salinities at various locations of the Delta. These variables are simulated in two steps: hydrodynamics and water quality.

Hydrodynamics of the Delta is described by governing equations for long wave, non-uniform, unsteady flows in prismatic channels. These equations coupled with continuity equations are solved by different numerical schemes for flows, stages, and velocities at discrete locations. The fundamental assumptions made in deriving the governing equations for the hydrodynamics of the Delta are: The flow is assumed to be one dimensional, i.e. the flow in the channel can be well approximated with uniform velocity over each cross-section and the free surface is taken to be a horizontal line across the section. This implies that centrifugal effect due to channel curvature and Coriolis effect are negligible. The pressure is assumed to be hydrostatic, i.e. the vertical acceleration is neglected and the density of the fluid is assumed to be homogeneous. The effects of boundary friction and turbulence can be accounted for through the introduction of a resistance force which is described by the empirical Manning or Darcy Weisbach Friction Factor equations.

The movement of water quality constituents, currently total dissolved solids, is explained by two distinct processes: advection and dispersion. The advection process is largely dependent on flow velocities which are obtained by solving the hydrodynamics equations. Dispersion process relies on the concentration gradient and the dispersion coefficient. The dispersion coefficients vary from a location to another and are commonly used as calibration parameters.

The DWRDSM is derived from work by the late Dr. Hugo Fischer of UC Berkeley. The model was specifically designed to simulate salinity changes in the Delta as affected by changes in geometry and hydrology. Solution schemes employed in this model are Methods of Characteristics and Lagrangian Methods for the hydrodynamics and water quality constituents respectively. The model is intended to be used in engineering studies on the effects of levee breaks, changes in net flow, changes in agricultural discharges, the effects of spreading waste discharges, installation of salinity control structures, dredging and/or diking of levees, or changes in the size and location of forebays. The model can also be used to examine the effects of different water project operational schemes. The model network includes 419 nodes, 500 channels, and 134 open areas (reservoirs or lakes).

A number of other mathematical models with similar functionalities have been adopted, enhanced and used in the past by DWR. Recent examples of these models include DWR/RMA and Fischer Delta Model (FDM). DWR/RMA is also known as Link-Node Model in which water is assumed to be stored at each nodal points and the flows between nodes are dictated by the head differentials between the nodes. The characteristics of the channels linking the nodes are specified as part of input data. The solution scheme employed by DWR/RMA is finite-difference method. The finite-difference method used in the solution of advection and dispersion is known to have the difficulties of numerical dispersion. The water quality module of the DWR/RMA has two different nodes dealing with tidal mechanics: intra-tidal and inter-tidal. FDM is a predecessor to DWRDSM. In fact, the solution schemes of DWRDSM are from those of FDM, version 7E. Improvements available in DWRDSM include flexible operation of hydraulic gates, incorporation of improved geometry description, change in downstream boundary location, refined description of agriculture drainage and diversion, streamlining the Fortran codes to make the code more reliable and easier to modify.

PARTICLE TRACKING MODEL (PTM)

The Particle Tracking Model simulates the movement and fate of individual particles in an estuarine environment. The developed model not only keeps track of the locations of particles subject to complex movements, but also allows modeled particles to undergo various fates over time and space. Positions of particles are tracked in three dimensions within a channel grid. Theoretical and empirical equations are used to simulate the advective and dispersive movements of particles. Velocity output in individual channels from a one dimensional flow model are expanded into a quasi three dimensional plane within the developed model. The movement of particles are governed by various kinetics. These include longitudinal advection, settling due to gravity (or rising due to buoyancy), transverse mixing, and vertical mixing.

The model is being applied to the Sacramento-San Joaquin Delta. It has been and is being used to help explain the complex hydrodynamics within the Delta and to evaluate project operations. Other applications include simulating the transport and fate of fish eggs and larvae. Striped Bass was used for the initial application but the model has also been applied to Delta Smelt and Winter Run Chinook Salmon.

TRIHALOMETHANE (THM) MODEL FOR THE SACRAMENTO-SAN JOAQUIN DELTA

DWR has developed a THM computer model to assist in the study of proposed solutions to Delta water quality problems. This planning model can be used to (1) study impacts of existing organic and inorganic THM precursor sources on drinking water quality; (2) evaluate potential benefits realized by employing different structural and non-structural source water management and strategies in the Delta; and (3) provide guidance in setting data collection priorities.

The Delta THM computer model requires input on Delta hydrodynamics and precursor transport from the DWR Delta Simulation Model (DWRDSM). DWRDSM is capable of predicting water quality at any existing and proposed drinking water diversion. The THM model also requires input on water treatment conditions to simulate the chemistry of THM formation and bromine substitution. The model can predict THM formation potential (THMFP), a surrogate measure of source water organic precursor content. The model can also predict Simulated Distribution System THMs (SDS-THMs), a surrogate measure of THM formation in a drinking water distribution system. The Delta THM computer model is currently being modified to predict the formation of other disinfection by-products such as haloacetic acids.

DATA, DATA BASE AND DATA ANALYSIS FOR THE SACRAMENTO-SAN JOAQUIN DELTA

DWR's Modeling Support Branch has established an extensive data base for the Sacramento-San Joaquin Delta. The data has been collected over the past decades by different agencies for various purposes. Fast, easy and accurate access to this data is now possible through the established data base. A number of different mathematical analyses of the data is also possible on line. Different forms of data display enable fast investigation of historical data.

The data base include stages, flows, EC, PH, DO, Organic and Inorganic constituents, water Temperature, Wind speed, Barometric pressure, and other information pertinent to the Delta.

The data base used is the U.S. Army Corps of Engineers' Hydrologic Engineering Center Data Storage System (HECDSS). An interface was written to allow menu-driven access to the data by a variety of plots and mathematical manipulations. Time series and scatter plots are the two most common static plots. Animated spatial and profile plots are available. The data can be processed by combining series using arithmetic operators; logged; moving averages or differences computed; transformed between EC, CI, and TDS; and filtered in the frequency domain with discrete Fourier transforms. The combination of an extensive data base with accessible graphics and mathematical operators allows staff to perform some analyses without the use of simulation models.

MINIMUM DELTA OUTFLOW (MDO) MODEL

The Minimum Delta Outflow (MDO) computer program computes minimum Delta outflow requirements due to various water quality and flow standards in the Delta. Previously, MDO was run as a separate, adjunct program to DWRSIM. It has now been merged with DWRSIM and provides consistent treatment of Delta consumptive use with DWRSIM. The program was described in detail in WRINT DWR-134B of the D-1630 hearing and in Phase I testimony.

MDO computes outflow requirements in two parts, (1) minimum required Delta outflow and (2) carriage water. Minimum required Delta outflow is the net outflow required to meet Delta quality standards independent of export pumping. Carriage water is any additional outflow required above the minimum due to export pumping.

CCWD has developed a methodology for predicting salinity as a function of antecedent outflow. This methodology is often referred to as the "G model". CCWD has recently provided the coding necessary to merge the "G-model" into MDO. DWR is currently investigating the incorporation of elements of the G-model into the MDO model. In the meantime, both DWR and CCWD staffs have cooperated to share information and ideas for further refinements

BIOLOGICAL MODELS

A number of models are presently used to evaluate the fisheries impacts of different alternatives. Methods used include Abundance Index Regression Models, the Wendt Striped Bass Model, the DFG Striped Bass Model and the Smolt Survival Model. Some of the major strengths and weaknesses of these models are summarized below.

Abundance Index Regression Models

Description:

Abundance indices for Crangon shrimp, Neomysis shrimp, splittail, longfin smelt and starry flounder have been developed by DFG using two sources of fisheries data: 1) Fall midwater trawl surveys, and 2) the San Francisco Bay/Outflow study. The indices were compared to Delta outflow for a number of different time periods. DFG then examined the relationships with high correlation coefficients, and chose those examples which seemed biologically reasonable.

Strengths:

-The models are very simple to apply.

-Effects at more than one trophic level can be evaluated.

Limitations:

-The models need to be verified..

-A cause and effect relationship between Delta outflow and species abundance indices cannot be substantiated at this time.

-Relationships have been found for relatively few species which may not be representative of the system as a whole.

-The relationships for at least some of the species may have little practical value for management because they are "driven" by wet years, when the projects have little effect.

-Relationships may not be valid if facilities are changed or the introduction of new species produces fundamental changes to the historic food chain.

-Population levels of a number of estuarine species may be regulated by ocean conditions, not outflow.

-Some indices do not differentiate between life stages.

Wendt Striped Bass Model

Description:

The model was developed by Phil Wendt (DWR) to estimate the number of striped bass lost as a function of fish abundance (Striped bass index), bass size (mm), mean monthly flow at Jersey Point (cfs) and export rate (cfs). Multiple regression equations were developed for June, July and August using historical data (1968-1980) on fish salvage at Skinner Fish Facility versus Striped bass indices (annual), average monthly export (CVP and SWP) and flow. Striped bass losses (individuals not yearling equivalents) are then calculated from the salvage results using equations for predation, screening efficiency, handling and trucking losses from an old version of the Fish Loss Model. The model was updated by Glen Rothrock (DWR) by adding data from 1987-1989 and deleting data from 1968-1970 (Clifton Court Forebay not in operation yet). Calculation of fish losses was also improved using a more recent version of the Fish Loss Model. Copies of the most recent model are available on request from DWR.

Limitations:

-DWR particle tracking studies indicate that reverse flows are a poor indicator of entrainment at the export facilities. Therefore, it is unclear why fish loss should be correlated with reverse flow.

-Relationships may not be valid if facilities are changed or the introduction of new species produces fundamental changes to the historic food chain.

-Models need to be validated using other years (after 1989).

-Including CVP exports in the model is questionable because the results are based on salvage at SWP only.

DFG Striped Bass Model

Description:

A relationship between the number of legal sized adults, Young of the Year indices (YOY) and the Loss Rate index forms the basis of this model. The Loss Rate index is a relative measure of the mortality rate of a given year class and is equal to the estimated combined CVP and SWP export losses (after the YOY index has been set) divided by the YOY index. Equations were then developed to predict what the loss rate and YOY index should be based on export and outflow conditions. A spawner-recruitment relationship is used to adjust the YOY index based on the initial adult population size.

Limitations:

-The model is not statistically rigorous. Error propagation through the model's numerous equations and autocorrelation in the data set severely limits its predictive ability.

-Electric Power Research Institute studies indicate that the model does not account for large changes in mortality associated with food limitation.

-The model predicts the adult striped bass index based on the average hydrology for a 5-year period, which may be difficult to use for planning purposes.

-The critical months selected for the loss rate and YOY models may cover too broad a time period. Similar correlation coefficients have been obtained for shorter time scales.

Fish Loss Model

Description:

A PASCAL model has been developed to estimate direct losses of Chinook salmon, steelhead trout and striped bass using assumptions in the DWR/DFG Two Agency Fish Agreement. The model involves two major steps: 1) estimation fish salvage for the export level of interest and 2) calculation of fish loss. To calculate fish salvage, the assumption is made that the density of fish collected at Skinner Fish Facility will be similar to estimated salvage for the 1979-1991 period. Under this assumption, more pumping means proportionally more fish enter the forebay and are salvaged at the screens. The model estimates fish loss by back-calculating from the number of fish expected to be salvaged at Skinner Fish Facility. Direct loss is computed as the sum of predation loss (pre-screen loss), screen loss, handling and trucking losses. Finally, all fish losses are reported in terms of yearling equivalents using growth and survival data developed by DFG. Copies of the model are available on request from DWR.

Strengths:

-The model is useful for examining the effects of changes in the export schedule.

-Direct effects of project operations can be addressed.

-The results of the model are standardized as yearling equivalent losses.

Limitations:

-The model has not been (and perhaps cannot be) validated.

-This model is most useful for comparing the relative change in fish loss between alternatives. The actual loss numbers may not be realistic because of uncertainties about salvage, screening and predation rates, described below.

-Daily salvage numbers have errors of ± 50 to 100 percent, depending on the total number salvaged.

-Salvage rates could change as a result of long-term trends in fish populations and from alterations to Delta "plumbing".

-Screen efficiencies are based on the DFG/DWR evaluations conducted in the late 1960s and do no reflect changes made in the 1980s which probably led to improved efficiency. Improved screen efficiency may cause the currently-used relationship between salvage and loss to overestimate current direct losses.

Smolt Survival Model

Description:

An empirical regression model has been developed by Kjelsen et al. (1992) to predict survival of fall-run hatchery smolts through different reaches of the Delta. Separate models have been developed for the Sacramento and San Joaquin Rivers. The principal factors in the Sacramento River model are water temperature, Delta Cross Channel and Georgiana Slough diversions and Delta exports.

Strengths

-Model may provide at least an indication of relative changes in salmon smolt survival resulting from different flow patterns through the Delta.

Limitations

-Survival of hatchery fish does not replicate survival of wild salmon moving through the same channels.

-The studies used in the development of the models may have been compromised by annual variation in the quality and size of fish.

-The predictive ability of the models is questionable because they are based on relatively few data points.

-The San Joaquin model is at least an order of magnitude less sophisticated and reliable than the model used on the Sacramento River.

-The model may be impractical for management purposes because the major variable, temperature, is essentially not controllable through project operations.

-Most release studies were performed during warmer months and may not be representative of other times of the year.

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