SDWA Testimony by Alex Hildebrand for presentation at the 1/16/07 Workshop of SWRCB re South Delta Salinity

Introduction

The noticed subject of this workshop is to "conduct detailed discussion on the southern Delta salinity objectives," with regard to "sources, concentrations, loads, and effects of salinity, and methods for its control in the southern Delta." The South Delta is highlighted on the accompanying slide and the current objectives are also shown.

In response to that notice my testimony is in several parts. First, I will discuss the sources and distribution of salt load and what has caused that salt load to be concentrated to damaging salinity levels in South Delta channels. Current salinity standards are substantially above the salinities that prevailed prior to operations of the CVP and SWP.

Second, I will discuss the reduction of yields of South Delta crops as a result of irrigating with water with salinity above the current 0.7/1.0 EC salinity standard. I will discuss the impacts that result from allowing salinity to fluctuate significantly above the monthly salinity standard during substantial portions of typical months. We will also discuss the need to have varying locations of salinity monitoring points in order to reflect the highest salinity that can be expected in each channel reach, and why those locations may vary with different modes of operation of tidal barriers and other flow control measures. The SWRCB has stated that when a standard is established for an area it is intended to apply throughout the area.

Third, I will discuss the inadequacies of the South Delta Improvement Program (SDIP) in meeting salinity and dissolved oxygen (DO) standards. I will indicate the additions to the SDIP which will enable it to meet those standards at all times while also providing the water levels and water supply needed by local diverters. No unreasonable measures or serious burdens on other water users are required.

My testimony is intended to provide an overview of what causes salinity problems and how salinity can be managed. In order to keep my testimony straight forward, I will not repeat the proofs of my statements that have been submitted in prior proceedings by SDWA, by the U.S. Salinity Laboratory, by the U.S. Extension Service, etc. That prior testimony will be introduced by reference and will be explained in detail in testimony by Terry Prichard.

<u>Sources of salt load and mechanisms that concentrate that load to damaging salinities</u>

There are two primary sources of salt load. First, there is a substantial indigenous salt load. That is the salt load that derives primarily from the weathering of soils that reduces rocks to gravel to coarse soils to silt. The chemical composition of this indigenous salt varies between soils that derive from granite on the east side of the San Joaquin Valley, and soils that derive from the weathering of marine shales on the west side of the Valley. In either case these indigenous salts are released to the river system and flushed to the ocean primarily during high flows. Those high flows dilute the indigenous salt load to low, non-damaging salinity as it is conveyed to the Bay and ocean. Prior to operation of the CVP and SWP, the salinity is South Delta channels was lower than is now allowed by current standards, except during fall months of years of extreme drought, such as 1931. As you can see from the slides, salinity at Vernalis was significantly lower before project operations began. Since these indigenous salts are not a problem, they do not need to be regulated unless they are mobilized by irrigating unleached dry lands during low river flows.

The second major source of salt load is salt that is imported into the San Joaquin watershed and South Delta by CVP and SWP operations. Tidal flows bring salty Bay water into the western Delta. CVP and SWP export operations then draw Sacramento water from the north Delta to the South Delta by reducing water levels and depths in the South Delta. This flow across the Delta entrains some of the salty Bay water that is in the western Delta as a result of tidal flows. That entrained Bay salt is greatly diluted by Sacramento water. However, about half a million to a million tons of this entrained salt is then delivered each year to the CVP's west side service area, either directly via the Delta Mendota Canal (DMC), or indirectly via the San Luis Dam where CVP and SWP export waters are commingled with their salt loads.

DMC water is delivered to westside farm lands (including the "exchange contractors") and to wetlands. Most of this water is then consumed by these crop and wetland plants. This is because the root systems take up water and evaporate it through the plants' leaves as a necessity of plant growth. However, the osmotic root systems reject the salt that is in the consumed water. The rejected salt is thereby concentrated and then flushed from the root zone with a small 'leach fraction" of water which is excess to the water consumed by the plants. This concentrated salt then either accumulates in the soils and ground waters, below the root zone or it flows to the river. The flow to the river is primarily via the drainage water pumped from the "tile" drains, and by subsurface accretions that flow into the river, and by intermittent drainage of water from wetlands. Roughly forty million tons of this imported salt has so far accumulated in the soils and groundwaters below the crop roots. However, hundreds of thousands of tons of this salt also flows into the river in most years. This is by far the major source of salt load in the San Joaquin River and South Delta, particularly in summer months. The salt in drainage water enters the river at concentrations (salinities) that are roughly three to seven times the 0.7 EC standard at Vernalis. Measures are planned to reduce the salt in the river by retaining more salt below the root zone. Waste discharges from growing cities also add salt load to the river at salinities above the salinity of their source waters. This happens either by direct discharge or by land disposals that increase the subsurface accretions to the river or to South Delta channels.

The availability of low salinity water to dilute the drainage water in the river and South Delta has been substantially decreased. This is primarily due to CVP exports south from Friant Dam, and to increased exports of Tuolumne River water to the Bay Area, and to a managed reduction of summer flows in the river when the inflow of drainage salt is greatest in order to shift the time of flow to increase spring flows for fish, and due to increased consumptive use of water to grow food crops. The FERC flows required from the Merced and Tuolumne Rivers help provide some San Joaquin flow during dry summers. The June 1980 technical report by USBR and SDWA determined the decrease in Vernalis flow that occurs due to operations of the CVP. In an average year the reduction is over 500 TAF as shown on the slide.

The human population in California is about three and one half times what it was in 1950 when the CVP went into operation in the San Joaquin watershed. This population growth has so far increased the public’s need for food, and for fiber to make clothes, by about that factor of three and a half. Furthermore, the rest of the nation relies on California for a large portion of the nation’s fruits, nuts, and vegetables. Agricultural Code 411 stipulates that neither the State nor the nation should be allowed to become dependent on a net importation of food. Farmers have until now had enough water to respond to that need. But this has substantially increased the consumptive use of water and decreased the inflow to the Delta. However, much of the salt that was in the consumed water still flows to the Delta.

Reduction of crop yields when existing salinity standards are not met

In prior proceedings, including 2005 CDO Hearings, SDWA has presented the various studies and investigations which resulted in the development of the current standards. In addition, we have presented information showing significant crop damage resulting from the use of water above the 0.7 EC standard as well as testimony estimating the economic impact to the area as a whole resulting from incremental increases in salinity.

A. Sensitivity of crops to salinity of irrigation water

An increase in the permitted salinity in South Delta channels has been advocated in previous proceedings by parties who believe that they would benefit by decreasing the protection of South Delta crops. These parties have asserted that South Delta farmers would not be adversely impacted by irrigating with channel water having salinities higher than the 0.7/1.0 EC standard. As explained in prior proceedings this contention is erroneously based on an invalid rehash of old crop salinity sensitivity data without regard to limitations of that data as applied to South Delta crops and soils. These limitations were explained in expert testimony by the U.S. Salinity Laboratory, the U.C. Extension Service and others. Dr. Glenn Hoffman of the U. S. Salinity Lab testified that the basic root zone salinity tolerance data on which the tables are based are difficult to relate to field conditions. They were based on large part on tests using weekly irrigation and 50% leach fractions on highly permeable soils. There was no pretense of coping with such factors as variations in salinity tolerance at different stages of growth, cultural soil compaction, commercially necessary departures from “as needed” irrigation, variations in leach fraction with time during the crop season, root aeration problems which occur when soaking for high leach, soil variations within fields, or soil damage by precipitation. As an example, Dr. Glenn Hoffman cautioned that:

> In addition to the generalized salt tolerance of crops . . . some crops may be more sensitive during emergence than during later stages of growth. . . . Some crops are salt sensitive at the early seedling stage. Data from literature indicate that barley, corn, rice, and wheat are most sensitive between emergence and the four-leaf stage. (Hoffman, et al., Water Quality Considerations for the South Delta Water Agency.)

1) The parties wanting to increase salinity have ignored the fact that the salinity sensitivity of crops varies during different stages of plant growth. They have only addressed established plants. Seedlings are typically more salt sensitive than established plants. Furthermore, plants are sensitive only to the salinity of moisture in the soil within the root zone, and this salinity rises between irrigations as the moisture in the soil is depleted. Seedlings have a very shallow root zone from which moisture can be lost by surface evaporation. Prior expert testimony also discussed the difficulty in replenishing that shallow soil moisture without eroding the soil around the seeds and seedlings, or creating a surface crust that interferes with seedling emergence. Terry Prichard's testimony will address this.

2) Proponents of increased irrigation water salinity have assumed that soil salinity will be diluted by rainfall. Beans and other crops do not germinate until the days are long enough and the soil temperature is high enough. By that time, most or all of the rain moisture has evaporated from the shallow soils around the seeds. The contention that established plants will benefit all summer from rain that fell in the winter is dubious at best. Terry Prichard will address the errors in assumptions about dilution by rainfall.

3) Proponents of increased salinity have also assumed that "leach fractions" of 25% or more are commercially feasible for South Delta crops on South Delta soils. Extensive prior testimony established that a large portion of South Delta soils have very low permeability (slow percolative capacity). This high "leach fraction" therefore often can not be achieved in commercial practice.[1]

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[1] See CDO transcript November 21, 2005, rebuttal testimony of Terry Prichard.

Alfalfa is a major South Delta crop in support of the large San Joaquin County dairy industry. We previously explained in rebuttal testimony on November 18, 2005, (CDO Hearing) that this perennial crop consumes a lot of water because it produces a large tonnage of crop. Percolation of sufficient water for this crop into the root zone is slow both because of low soil permeability and because the surface soil is compacted by the cultural operations of mowing, raking, baling, and road siding. A cutting must be harvested every month to obtain quality hay. Furthermore, harvest operations and hay curing take time. It is therefore only possible to irrigate alfalfa twice a month in most situations. Alfalfa can not be given a prolonged soak during each irrigation because the plants are easily damaged by prolonged submergence. Feasible "leach fractions" are consequently small. A lower salinity of irrigation water is therefore needed in order to offset the low leach fraction and thereby maintain a soil moisture salinity that is low enough to avoid crop loss. Since alfalfa is a fairly deep rooted crop, soil moisture of low salinity can in some degree be percolated during periods of slow crop growth and then depleted during summer growth. However, there must be adequate long term soil moisture replenishment to meet crop needs. The result is that, although alfalfa can tolerate a higher soil moisture salinity than beans, the irrigation water salinity that can provide full crop yield is about the same for alfalfa as it is for beans, carrots, onions, and berries.

Consequently a 0.7/1.0 EC salinity is only marginally adequate for important crops grown on South Delta soils.

4) Analyses presented by some parties assumed that leach water flows uniformly through the root zone so that salt is uniformly flushed. As I stated in prior testimony, I was previously the Director of a major oil fields research laboratory. We did extensive research on the flow of fluids through earth materials. The flow goes selectively through the larger, better connected pores and only partially flushes other pores. The "leach fraction" needed to flush salts from a root zone with typical South Delta soils, is, therefore, more than the sensitivity tables assume. The tests on which the tables are based were made with uniform soils that had high permeability, and the tests were made with very large "leach fractions."

B. Damage resulting from periods when salinities are above the salinity standard as would be permitted by SDIP

The operation of CVP and SWP export pumps draws down water levels and depths throughout the South Delta on order to induce a north to south flow across the Delta. This reduction in level and depth is more at high tide than at low tide. The tidal excursion is therefore also reduced. In the absence of corrective measures the depth of water can become so low that local diversions by farmers becomes impossible and crops are lost. The accompanying slide shows the most recent example of a southern Delta channel being almost dry while exports were high. Temporary barriers have been used to largely correct this depth problem in the short term. However, the temporary barriers do not control salinity.

The accompanying slides illustrate the flow and salinity distribution with temporary barriers. As you can see, there is a very small net flow over the Middle River (as well as the Old River) barrier which indicates the large null zone behind it. To correct this problem in the future, the SDIP proposes to install tidal barriers that capture high tide waters for diversion during low tides. However, the high tide water captured by the barriers would often be insufficient, particularly during neap tides, to supply irrigation needs. A substantial flow of water is therefore required into the head of Old River from the San Joaquin channel to maintain adequate water depth. In summer months during periods of above normal temperature this required inflow is forecast by DWR to be about 700 cfs during periods of neap tides that occur twice in each lunar month.

There is no regulatory minimum summer flow at Vernalis. Vernalis flow is often too low to supply that inflow to Old River. If the inflow is supplied by drawing an intermittent reverse flow from the central Delta to the head of Old River via the Stockton Ship Channel, it is impossible to maintain water depth in the San Joaquin channel, or to meet the salinity standard at Brandt Bridge or the dissolved oxygen (DO) in the Ship Channel. The water depth at the head of Old River has to be reduced in order to induce a reverse flow. The SDIP not only ignores the depth and salinity needs in the channel from Vernalis to Stockton, it also would exacerbate problems in that channel. The second attached diagram illustrates what happens if flow reversals at Brandt Bridge are permitted.

In order to comply with the salinity standard through Middle River, Grant Line Canal and Old River within the South Delta it is not sufficient to only maintain an adequate depth. It is not possible to control either salinity or DO in a channel reach when there is inflow at both ends to meet the channel depletion requirements. There must therefore be sufficient inflow at one end of each reach to supply diversions within that channel reach plus an adequate net flushing flow out the other end of the reach. In other words, there must be a net unidirectional flow. Furthermore, the inflow to each reach must be of adequate quality so that the net flow out of the reach still meets the salinity standard. Crops irrigated from the channel must be able to consume water as a necessity of growth. The leach water that drains back to the channel therefore contains the same salt load that was contained in the inflow to the reach, but the concentration (salinity) is increased. The inflow to each reach must therefore be of sufficient quality to allow for the concentration of incoming salt. Very little salt load is added by Delta crops. The process proposed by the SDIP and the quality of inflow proposed into each reach are not adequate to meet the salinity standard at all times and locations in each reach, particularly during neap tides. Crops must be irrigated whenever and wherever needed. Crops are damaged if the salinity standards are not being met at that time and location of diversion.

The next two slides illustrate these two points. The first shows how the SDIP proposes to operate at lower water levels than exist with the temporary barriers. The second slide shows a possible operating scenario under the SDIP. First, you should note that this scenario does not include the Head of Old River barrier. At this time, it is unknown if the pelagic fishery decline will allow such operation.

This slide shows the flows in each channel associated with a Vernalis flow of 1,000 CFS. That is the Vernalis flow that occurred during most of the summer of 2004. During neap tides, the Tracy Old River barrier is only able to capture 125 CFS and only 300 CFS during spring tides. This is much less than is needed to supply local diversions in Old River and Tom Paine Slough. The remaining flow to meet that need must therefore come from inflow from the San

Joaquin channel through the Head of Old River and past the channels which connect to Grant Line Canal. This means that in order to maintain even a marginal water level in Old River between the connecting channels and the Tracy Old River barrier, there must be an inflow into both ends of that channel reach. Consequently, there will be a stagnant zone with no net unidirectional flow. Neither the salinity nor the DO standards can be met in a stagnant reach. If the barriers are operated to flow into Grant Line Canal and out through Old River, the salinity standard can also not be met. 0.7/1.0 EC water containing an imported salt load will have been increased salinity due to consumptive use of a substantial portion of that water as it flows to the head of Old River and thence past the Old River barrier.

The slide shows a reverse flow from the ship channel up through the San Joaquin channel to the head of Old River. In order to induce this reverse flow, the water level at the head of Old River must be reduced below the level in the ship channel. This would exacerbate the problems of inadequate depth in the San Joaquin River Channel. Furthermore, the reverse flow cannot be consistently maintained and flow reversals would result in periods of stagnation and failure to comply with the DO standard and with the salinity standard at Brandt Bridge. These problems can be corrected by using low lift, fish-friendly pumps to augment flow through the Old River barrier and recirculation of DMC water when necessary to augment flow and decrease salinity at Vernalis.

<u>Means by which the 0.7/1.0 EC can be met throughout the South Delta at all times except during extreme drought</u>

Proponents of increased salinity have asserted in past proceedings that compliance with the 0.7/1.0 EC standard may not be possible, and would require an unreasonable release of stored project water. In those previous proceedings they have not attempted to prove those contentions, or to examine reasonable ways to comply with the standard. The standard can be met by a combination of reasonable measures.

1) Install fish friendly, low lift pumps at one or more of the tidal barriers.

These pumps would supply on an as needed basis most of the flow and volume deficit which the barriers do not currently capture. They would thereby assure that adequate water depth is maintained at all times. They would also assure that unidirectional flow is maintained in each channel reach to avoid periods of stagnation and loss of salinity and DO control. Furthermore, they would bring in export quality water. That water is better than the salinity standard, and hence would permit some concentration of the salt in the inflow water as it flows toward the exit in each reach. This recirculation of water within the South Delta involves no water cost to any party, and requires only a modest power cost. However, this measure would assist, but by itself would not result in compliance with the Brandt Bridge standard.

2) Recirculate water from the DMC to the river and back to the Delta.

During summer months (July through September) there appears to be no unacceptable net fishery impact when water is recirculated by delivering Delta water to the San Joaquin River via the DMC and the Newman or other Wasteways, and then back down the river to the Delta. This recirculation was demonstrated in August of 2004 at a time when Vernalis flow was about 1000 cfs. That 1000 cfs flow was only marginally adequate to maintain water depth from Vernalis to the head of Old River, and the salinity at Brandt Bridge could then not meet the standard with only 0.7 EC at Vernalis. 250 cfs was released through the Newman Wasteway while New Melones releases were kept constant. This flow increased the water depth at Vernalis by about half a foot and lowered salinity by about 0.1 EC. When there is 0.6 EC at Vernalis, it comes close to providing 0.7 EC at Brandt Bridge providing the inflow to the head of Old River is sufficiently reduced by the low head pumps at the tidal barriers so that an adequate downstream flow continues past Brandt Bridge.

3) From mid-May to July 1 the above type of DMC recirculation might be detrimental to fisheries. At those times the increase needed in Vernalis flow and quality can be obtained by using borrowed water which is replaced later. For example, water can be borrowed from San Luis Dam in June and replaced in July and August. Or it can be borrowed from deliveries being made to subsurface or surface storage south of the Delta during June and replaced in July and August. It may also be possible to provide spring fish flows in ways that do not reduce Vernalis flows from mid-May to July 1.

4) There are times when Vernalis flows are more than adequate, but reducing Vernalis salinity in order to comply with the Brandt Bridge standard would require large amounts of dilution from New Melones or recirculation which may entail substantial costs. In that situation drainage to the river from the CVP westside service area could be curtailed. This would substantially reduce river salt load at a time when the associated loss of flow was not a problem.

5) Other potential measures include tidal flow control at Franks Tract to reduce the entrainment of Bay salt and reduce the DMC salt load. Construction of a valley drain would keep most imported salt out of the river. A new dam at Temperance Flat would increase available dilution water.

These and perhaps other measures can be combined in ways that are optimum for each situation. It is not clear that any substantial releases of stored water are necessary to comply with the 0.7/1.0 EC salinity standard.

<u>Summary</u>

1) Sources of salt load in South Delta channels

Prior to operation of the CVP and SWP there was no salinity problem in the South Delta except briefly during extreme drought. Natural processes release a substantial salt load into the river system, but these native salts enter the system during high flows. They are therefore flushed through the South Delta toward the Bay with ample dilution and low salinity.

Operations of the CVP and SWP cause a large importation of salt into the San Joaquin watershed that was not previously there. Tidal flows bring Bay water into the western Delta. The export projects then draw Sacramento water from north to south, and entrain some of this Bay water. Consequently, the CVP delivers a large load of this salt (millions of tons) to its westside service area via the Delta Mendota Canal. Part of this salt then drains to the river via drainage from farm lands and wetlands. This imported salt thereby creates the South Delta salinity problem.

2) Measures that concentrate the imported salt load

a) All plants, including farm crops, must take up water through their roots and evaporate it through their leaves as a necessity of plant growth. However, the osmotic root system rejects the salt in the consumed water. The salt must then be flushed from the root zone with water in excess of what is consumed. This process concentrates in the drainage water the salt that was in the irrigation water. Drainage from the CVP service area typically enters the river at three to seven times the 0.7 EC Vernalis salinity standard.

b) River flows that dilute this imported salt have been reduced by exports from the watershed, by shifts in time of river flow away from the periods of largest drainage inflow, and by increases in consumptive use to grow the food that is needed as the human population increases.

c) Even when New Melones releases are made to comply with the Vernalis standard, the imported salt load is still there. Farm crops in the South Delta necessarily reconcentrate that salt load so that salinity again rises somewhat as the Vernalis flow goes downstream.

3) Determining the channel water salinities that can provide irrigation water that is adequate to provide full crop yields in the South Delta is a very complicated process, as shown by the testimony which led to the 0.7/1.0 EC standard. The permeability of many South Delta soils is very low. High "leach fractions" are not feasible. The salt sensitivity of seedlings is greater than the sensitivity of established plants, and it is difficult to control soil moisture salinity in the shallow root zone of young plants. There has been no change in the science involved in salinity versus crop yields. We see no reason to expect that a change in EC standard would result from a repetition of the thorough analysis that took place at the time the standards were established. We do believe that the implementation of the standards should avoid large fluctuations in salinity during a lunar month, and that there should be monitoring that better represents the location of maximum salinity within each channel reach during each mode of in-channel flows caused by barrier operations and recirculation via the DMC or with low head pumps.

4) Measures to comply with the salinity standards

My testimony explains how the standards can be met by a flexible combination of measures that do not require substantial new releases of stored water. These measures include; (a) fish friendly, low lift pumps at one or more tidal barriers to maintain needed flow into each channel reach and to maintain unidirectional flow through each reach, and to bring export quality water into internal channels, and to assure that adequate depth is always maintained for local diverters; (b) recirculation of DMC water via the river during July through September to provide adequate flow at Vernalis and facilitate meeting the salinity standard at Brandt Bridge; (c) when fishery concerns preclude this DMC recirculation, such as in mid-May through June, borrow water from San Luis Dam or indirectly from other storage, to provide Vernalis flow and quality and replace that borrowed water in July or August; (d) alternatively seek water purchases and exchanges; (e) release water from project storage only as a last resort.

We have explained why we have a salinity problem and how it can be cured.