APPENDIX A

San Joaquin Valley Historic Planning and Geologic Inventory

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APPENDIX A

San Joaquin Valley Historic Planning and Geologic Inventory

Envisioned Discharges and Salt Loads

Planning

Agricultural development has continued in the western SJV despite salinized soils. Lands were classified in the San Luis Unit (SLU) (Figure A1) starting in 1954 as to their suitability for crop productivity and management cost (USBR, 1978; Ogden, 1988). The SLU includes agricultural lands that total over 700,000 acres in the Westlands, Panoche, Broadview, Pacheco, and San Luis Water Districts of the Grassland and Westlands subareas (USBR, 1981). Limiting factors were soil, topography, and drainage. Lands were considered flawed because of the presence of alkali (i.e., salt), hardpan (i.e., impeded drainage), and roughness (i.e., uneven land surface). The irrigation service area that required drainage continued to increase. By 1962, 12% of the SLU was comprised of Class 4 lands (i.e., lands known to have a reduced payment capacity for irrigation/drainage improvements based on agricultural return). These were mainly in areas directly affected by erosion from the Coast Ranges to the west (USBR, 1978). A larger segment of Class 3 lands (i.e., lands known to require difficult and costly management) were identified adjacent to the valley trough. Through time, agriculture has expanded increasingly into Class 4 lands. This expansion into Class 4 lands was controversial since these lands were considered to require the most capital for drainage removal and have the least ability to pay for drainage improvements. Recent plans again include further expansion of the *place of use* for CVP water supplies by WWD (CH2MHILL, 1997).

Historic estimates of drainage needs (i.e., estimates of envisioned rates of flow or volume of drainage in acre-feet to lower the water table) provide an interesting context for modern estimates. Although the amounts of drainage for conveyance out of the SJV have increased since planning began in 1955, the design capacity of the main component of a drainage facility has remained relatively unchanged through time [i.e., 300 cubic feet per second (cfs)]. However, estimates vary for the rate of flow for the north and south ends of the drain (100 cfs in the south and 450 cfs in the north). Given below are examples of the many sets of values for drainage volume and drained acreage that exist throughout the planning history for a drain, but our review is by no means exhaustive. For example, references are mainly documentation by or for federal agencies and joint federal and state efforts (e.g., Hydroscience, 1977; USBR, 1978; SJV Interagency Drainage Program, 1979a; CH2M Hill, 1985; SJV Drainage Program, 1990a; USBR, 1992; SJV Drainage Implementation Program, 1998). A parallel set of reports that document early state planning efforts are not as extensively cited (e.g., CDWR, 1965a; b; 1969; 1974; 1978; CSWRCB, 1979). Many documents contain similar estimates (or reference the same data) based on generalized data for future conditions. For example, studies in 1979 and 1990 both state concern over 400,000 acres of affected farmland that needs drainage due to the high water table (SJV Interagency Drainage Program, 1979a; SJV Drainage Program, 1990a). Evaluations of alternative geographic disposal areas showing engineering and net revenue disposal benefit of different drainage conveyances (e.g., USBR, 1955; 1962; CDWR, 1965a; SJV Interagency Drainage Program, 1979b; Brown and Caldwell, 1986), mainly address management aspects, not source loads estimates.

Comparison of the amount of volume discharged per subareas is useful as a measure of hydrologic balance and hence, the volume of drainage expected. For example, in a 1988 analysis (CH2M HILL, 1988), the Northern and Grassland subareas were considered in hydrologic equilibrium which implies little future change in the extent of lands that need drainage. A distinction was made in the analysis between managing the accumulated hydrologic imbalance (area of drainage affected land) and managing the annual imbalance (rate of water table rise). Short-term objectives would work toward hydrologic balance by stemming the rate of deterioration while reclaiming existing problem lands would require releasing from storage a large accumulation of water, salt, and Se. Achieving hydrologic balance also would not achieve salt balance. Salts would continue to accumulate in the soils and aquifers of the SJV.

Besides estimates of flow and volume, historical documentation gave estimates of water quality (i.e., milligrams per liter total dissolved solids or specific conductance) on which to base annual discharge of salt (i.e., tons salt/year). Selenium analyses on which to base loads of Se were not available until the mid-1980's (Presser and Ohlendorf, 1987). The amounts of salt projected for discharge from the SJV, as a whole, help identify the magnitude of the salt build-up. Difference in the amounts of salt discharged per subarea help identify differences due to geology and hydrology in the affected areas. The affect of salinity on receiving waters is not considered here, only the magnitude of source salinity loads. Both the levels of salt and nitrate (7,604 tons of nitrate [NO_3 + NO_2 (N)] during the worst case year of 2020) were considered problematic in historical water-quality studies of the SLD (USBR, 1978; SJV Interagency Drainage Program, 1979a; b). Salt would aggravate problems of salinity intrusion into the Delta thereby interfering with beneficial uses of Delta waters and nitrates would disturb the balance of nutrient levels in the estuarine system thereby causing eutrophication and high turbidity levels. Limited data on toxicity and concentrations of other constituents of concern (e.g., nitrate, phosphate, pesticides, dissolved oxygen, boron, arsenic, heavy metals) present in agricultural drainage are listed in historical reports (CDWR, 1965a; SJV Interagency Drainage Program, 1979a; b; Brown and Caldwell, 1986; USBR, 1984b through h), but are not included here.

Specific Estimates

Both the SJV Interagency Drainage Program in 1975 and the USBR in 1977 and prepared estimates of discharge for the SLU (USBR, 1978). The 1970's planners envisioned an agricultural drainage canal with a design capacity of 300 cfs and a length of 197 miles. Estimates of the quantity of the SLU drainage discharge were calculated through the year 2080 (i.e., approximately 100 years into the future) and of quality through the year 2030 (Table A1). Maximum quantities of drainage were not anticipated for "at least another 100 years" in the original plan. But revised estimates showed the "ultimate" (i.e., maximum) quantity of drainage would be available by 2030 (Table A1). A hydrologic schematic of the *Ultimate Waterflow Conditions* developed for the SLU shows a drain discharge of 144,200 acre-feet/year from 300,000 acres underlain by subsurface drainage pipes (Figure A2). The historic numerical model simulations were based on salinity measurements. The model predicted that the discharge of the poorest quality of drainage would occur during early years of irrigation and drainage. As "equilibrium conditions" were approached between soil and water, concentrations of dissolved minerals in the drainage water were expected to decrease". The model also predicted salt concentration (mg/L total dissolved solids, TDS) would decrease by 50% after 40 years of drainage. The prediction was for the annual discharge of salt from the SLU would increase from 43,710 tons salt/year at the start of drainage provision to a maximum of 1.5 million tons salt/year after 40 years of discharge, as the volume of drainage water discharged increased (USBR, 1978).

In 1979, a final report was prepared by the SJV Interagency Drainage Program recommending completion of a valley-wide drain (i.e., encompassing five areas, North, Delta-Mendota, San Luis, Tulare Lake, and Kern County) which would discharge into the Bay-Delta at Chipps Island. The report also included a first stage environmental impact report (SJV Interagency Drainage Program, 1979a, b). Estimates of expected annual quantities of drainage ranged from 57,000 acre-feet in 1985 to 668,000 acre-feet in 2085 when acres drained were expected to reach over one million acres. Estimated tons of salt requiring disposal ranged from 3.1 million to 3.9 million tons of salt/year for a valley-wide drain.

In 1983, the USBR estimated drainage quantity and quality (i.e., concentration of salt, seven major elements, and twelve minor elements, but Se data was absent) for expected discharge to the SLD from the SLU during the period 1995 to 2095 (USBR, 1983) (Figure A3). Water-quality projections were based on concentration averages in the SLD for the period September 1982 to January 1983 (USBR, 1983), before the discovery of deformities at Kesterson NWR. Estimates of drainage volume ranged from 84,525 acre-feet in 1995 to 274,270 acre-feet in 2095 for the combined discharge from the San Luis Service Area (equivalent to WWD; 48,885 to 192,105 acre-feet) and the Delta-Mendota Service Area (encompassing Grassland subarea and other northern water districts; 35,660 to 82,158 acre-feet). A steady rise in discharge was predicted from 1995 to approximately year 2035 when the rate of increase slows but continues rising through the projected year 2095 (Figure A3). The worst-case scenario was to occur in year 2020 when 1.8 million tons of salt/year was to be discharged in 201,025 acre-feet of drainage.

In 1988, salt and water inflows and outflows to the SJV were conceptualized (CH2MHILL, 1988) (**Figure A4**). Calculations specific to the five subareas determined the annual groundwater and salt accumulation. Results of these studies showed volumes of water and tons of salt recharged or discharged by specific processes (e.g., evapotranspiration), sources (e.g., canal imports), or reservoirs (e.g., confined aquifer). The annual salt accumulation determined for the semi-confined aquifer in 1988 for all five subareas was 3.3 million tons of salt/year. The annual accumulation per subarea ranged from 1,000 tons salt/year to 1.5 million tons/year, due to differing hydrology, geology, and drainage options (see later discussion). An analysis for the Westlands subarea showed 44% of the salt was from dissolution of salts internal to the SJV, 49% imported from outside sources including irrigation water and 7% from other sources such as seepage. The predicted conditions in the Westlands subarea showed the largest proportion of internal salt to imported salt for the five subareas. Westlands subarea is the most impacted by Coast Range sources of Se because of its location on the Panoche alluvial fan (Presser et al., 1990; Presser, 1994b). For the Westlands subarea, importation of higher quality water would have a diminished effect compared to other subareas because of this large reservoir of salt. The Northern and Grassland subareas show high proportions of imported salt to internal salt and relatively low salt accumulations because of the availability of the SJR for salt discharge. A 1989 analysis for the SJV Drainage Program estimated that salt is accumulating at a rate of approximately 100,000 tons salt/year in the Grassland subarea (SJV Drainage Program, 1989). On a recent detailed basis, calculations for the lower SJR basin, that includes the Grassland subarea and recycling to and from the SJR, show a doubling of salt within the basin every five years despite drainage to the SJR (net gain of 207,000 tons salt/year of a mean salt inflow of 917,000 tons/year) (Grober, 1996).

Re-evaluation in 1998 of salt importation data (neglecting salt reservoir calculations as done in 1988) showed an excess of salt inflow over outflow in all subareas (SJV Drainage Implementation Program, 1998) (Figure A5; one railroad car is equivalent to 100 tons salt). The total annual imported salt was 1.5 million tons/year. This value does not include the calculated 620,000 tons salt/year discharged out of the valley through the SJR (SJV Drainage Implementation Program, 1998). No data were given for internal salt or the status of subarea salt reservoirs.

The input of 1.5 million tons salt/year calculated as part of the 1997-re-evaluation, is the value quoted in 1978 by the San Luis Task Force that reviewed the management, organization, and operation of the SLU to determine the extent to which the SLU conforms to the purpose and intent of Public Law 86-488. The task force noted that planning documents had looked 40 years into the future (1950 to 1990):

At about the 1990 level of agricultural development in the San Joaquin River Basin, slightly more than 1.5 million tons of new salt will be added annually to the valley from applied irrigation water (Page 161).

Current Management

The current implemented agricultural wastewater management plans for the five SJV Drainage Program subareas are:

- The Northern (26,000 drained acres) and Grassland (51,000 drained acres) subareas discharge agricultural drainage to the SJR. A state permit has been in place since 1998 to regulate drainage from the Grassland subarea to the SJR through use of a portion of the SLD as a conveyance facility (CCVRWQCB, 1998a). The SLD has been renamed the Grassland Bypass Channel for this project for re-use of a 28-mile section of the drain.
- Westlands subarea (5,000 drained acres, relieving salinization in 42,000 acres) has a "no discharge" policy, that is, storage of drainage in the underlying groundwater aquifer and use of agricultural water supplies and the aquifer for dilution. Some consider this a recycling program (SJV Drainage Program, 1989) although it has temporal storage, displacement, and distribution components to it.

Degradation of groundwater aquifers is expected to occur. Ground water with dissolved solids of greater than 2,500 mg/L is considered un-usable for irrigation (SJV Drainage Program, 1990a)

- Tulare (42,000 drained acres) and Kern (11,000 drained acres) subareas are internally drained basins that discharge to privately owned evaporation ponds. Discovery of bird deformities in 1987 through 1989 caused the state to call for closure of some ponds and operation of the remaining ponds under permits (CSWRCB, 1996a). State permits have regulated evaporation pond discharges since 1993 with various areas of mitigation wetlands required (CCVRWQCB, 1993, 1997, and 1998c). Many evaporation ponds have closed or are in the process of closure; remaining ponds have been modified to lessen bird-use. Documentation in 1999 (SJV Drainage Implementation Program, 1999d) showed the number of individual basins and pond operators decreasing by approximately 60%, but the surface area of ponds decreasing only from 6,715 to 4,895 acres,

Geologic Inventory and Reservoir of Selenium in the San Joaquin Valley

Selenium Geologic Inventory and Mass Balance

Salt (and by inference, Se) enriched sediment has been accumulating on the alluvial fans of the SJV for 1.0 to 1.2 million years, originating from Coast Range sources of marine sedimentary rocks (Bull, 1964; Deverel and Gallanthine, 1989; Gilliom et al., 1989; Andrei Sarna-Wojcicki, U.S. Geological Survey, Menlo Park, CA, personal communication, 7/23/98). Figure A6 visually illustrates some of the characteristics of the geologic sources of Se in the Coast Ranges, the SJV irrigation and drainage system, and potential Se reservoirs (i.e., Se inventory components). A summary of Se concentration and load data that are the basis of the conceptual model of Se sources, transport, and mobility is given in Figure A6.

The SJV has a net negative annual water budget (evaporation exceeds precipitation). Prior to development of the water management system, a permanent shallow groundwater table only occurred in groundwater discharge zones near the SJV trough. The present shallow ground water and attendant subsurface drainage flows are mainly the result of water management including massive irrigation. Micro-management seemingly has enabled agricultural production to continue at a high rate without excessive abandonment of lands.

An estimate of the time necessary to discharge the accumulated Se from the aquifers and alluvial fans of the SJV can provide some perspective on the size of the geologic and hydrologic reservoirs of Se. Estimates of the geologic and hydrologic reservoirs of Se within the alluvial fans and in the valley also provide perspective on the amount of Se potentially available for discharge via a drainage conveyance. Such estimates are necessary to understand the minimum bounds on how much Se would be discharged over the course of time should an out-of-valley conveyance system be built.

Prediction of Long-Term Selenium Reservoirs

Recent data collection in the area of the Panoche Creek alluvial fan has enabled a preliminary calculation of the reservoir of Se within the alluvial fans of the SJV; that is, the Se potentially available for discharge via a drainage conveyance over the long-term. To determine the time necessary to discharge the accumulated Se from the alluvial fans of the SJV, two methodologies for estimating the reservoirs are given:

1) based on known concentrations of Se in soils of the western SJV (especially the Panoche Fan or “problem acreage”) and neglecting the amount of Se in the groundwater reservoir;
2) based on suspended and dissolved Se loads brought down in runoff from the Coast Ranges in the area of the Panoche Creek alluvial fan.

Estimates Based on Alluvial Fill—Soils Scenario

General surveys of Se concentrations in soils across the western United States show an average of 0.34 micrograms Se per gram or parts per million (ppm). Across the conterminous United States the average is 0.26 ppm (Shacklette and Boerngen, 1984). Surveys of Se concentrations in soils of the western SJV were conducted in 1982 and 1985 (Tidball et al., 1986; 1989). The interfan area below Monocline Ridge and between Panoche Creek in the north and Cantua Creek in the south showed the highest Se concentrations (maximum ungridded value 4.5 ppm). The geometric mean for the Panoche Creek alluvial fan is 0.68 ppm Se (1985, 721 sites, 1.6 kilometer interval, 66-72 inch depth). Tidball et al. (1986; 1989) also found a geometric mean of 0.14 ppm for the SJV western slope (1983, 297 sites, 10 kilometer intervals, 0-12 inch depth).

The Se concentration in soils was extrapolated to estimate the amount of Se in the soil reservoir of the Panoche Creek alluvial fan. An average concentration of 0.68 ppm Se was employed along with several estimates of affected acreage, soil densities, and soil depths. Selenium deposition under the various conditions ranges from 2.7 to 356 million pounds (lbs) Se (Table A2). If a removal rate of 42,785 lbs Se/year is hypothesized (see later discussion, Appendix B), it would take 63 to 8,321 years to discharge the soil reservoir of Se in the Panoche Creek alluvial fan (Table A2) (Figure A6). This estimate does not factor in the loading that would occur over the course of that time due to further weathering and runoff from the Coast Ranges, nor the amount of Se in the groundwater reservoir.

Estimate Based on Panoche Creek Runoff—Runoff Scenario

No complete sets of data (i.e., flow, Se concentration in water and sediment, and amounts of sediment) exist for Panoche Creek prior to 1997. Reconnaissance in 1987 to 1988 (Presser et al., 1990) showed dissolved Se concentrations of 44 to 57 μg/L in runoff samples. Suspended sediment Se concentrations were relatively low (1.2 to 2.9 ppm Se), but the volume of sediment relatively high (10% or 91,500 mg/L). Estimation of runoff transported in the SLD in water year (WY) 1995 (a water year begins on October 1st), when extreme flooding in the Coast Ranges caused the drain to be used to collect runoff, showed a Se load of 1,750 lbs Se eventually discharged to the SJR (CCVRWQCB, 1996a; b; Presser and Piper, 1998). This amount represents 22% of the annual 8000-lb Se prohibition for discharge to the SJR enacted by the state in 1996. The runoff load for the one major storm of WY 1997 was estimated at 137 lbs Se based on monitoring downstream channels (USBR et al., 1998; Table B8). This amount represents 1.9% of the annual load discharged to the SJR in WY 1997. In 1998, 487 lbs was estimated transported by Coast Ranges runoff, representing 5% of the total load discharged though the Grassland Bypass Channel Project (USBR et al., 1999). These latter data represent approximations of anecdotal events and only should be used to assess the order-of-magnitude for runoff loads during an extremely wet year in WY 1995 (total precipitation greater than 11.5 inches) and a short duration series of storms (total precipitation of 0.6 inches) in WY 1997.

The rate of sediment and Se loading has been under study at Panoche Creek only since September 1997 (U.S. Geological Survey, 1999; Kratzer et al., in press). The recently installed gaging station provides flow data and hydrographs for WY 1998 storms. Storms of WY 1998 were the result of an *El Nino* year of precipitation and therefore represent an extremely wet year (see below, occurrence interval of large magnitude storms). Sediment and water samples were taken during flood events to determine dissolved, total, and suspended Se loads (U.S. Geological Survey, 1999; Kratzer et al., in press). The flow data are integrated with these Se concentration data to forecast dissolved and total Se loads, with suspended Se loads calculated by difference (Table A3). The forecast Se load measured in runoff discharged from Panoche Creek for two storms was 5,995 lbs Se (Table A3). Estimation of two intervening storms shows a total of 2,050 lbs. The total of the these forecast runoff loads of Se for WY 1998 is 8,045 lbs, with 16% of the load as the dissolved fraction and 84% as the suspended fraction. Although the concentration of Se in suspended sediment is relatively low (1-2 ppm Se) (Presser et al., 1990; T. Presser, unpublished data), the large volume of material leads to a high load in the particulate material as compared to the dissolved load. Calculations cannot be made at this time to estimate the load of Se discharged from the watershed to receiving waters to compare to input loads because of the lack of adequate downstream monitoring stations. So influx and efflux cannot be directly compared. However, 8,045 lbs Se/year source influx measured in the extremely wet year of 1998 is comparable to the state limitation on discharge from the SJV via the SJR, that is, an efflux of 8,000 lbs Se/year (CCVRWQCB, 1996c). In general though, under average rainfall amounts, the annual load from these natural sources is calculated to be a small percentage of the Se load potentially discharged from the SJV (USBR et al., 1999). Only when source loads from the Coast Ranges are considered in sum (see below) or during a year in which a large magnitude storm occurs, are the influx amounts significant compared to efflux amounts currently regulated.

The Se discharge data for Panoche Creek for WY 1998 were extrapolated to give estimates of the amount of Se deposition that has occurred over a time period of either 0.5 million years or 1.1 million years to give a range of accumulation. Deposition over these two time periods was calculated for one large magnitude storm in 10 years, one large magnitude storm in 50 years, or one large magnitude storm in 100 years. Table A4 shows amounts of total Se, dissolved Se, and suspended Se deposited under those conditions. The range of dissolved Se deposition over 0.5 million years is 13 to 86 million lbs Se and over the course of 1.1 million years, 28 to 188 million lbs Se. The range of suspended Se deposition over the course of 0.5 million years is 67 to 449 million lbs Se and over the course of 1.1 million years, 147 to 989 million lbs Se. The range of total Se deposition over the course of 0.5 million years is 80 to 535 million lbs Se and over the course of 1.1 million years, 175 to 1,177 million lbs Se. If the removal rate is hypothesized as 42,785 lbs Se/year (0.043 M lbs Se/year) (see later discussion, Appendix B), then it would take 1,870 to 27,510 years to discharge the reservoir of Se in the Panoche Fan based on total Se deposition from runoff (Table 4) (Figure A6). Ranges based on dissolved Se deposition from runoff are 304 to 4,394 years and based on suspended Se deposition from runoff are 1,566 to 23,116 years. These estimates do not factor in the loading that would occur over the course of that time due to further weathering and runoff from the Coast Ranges. The estimate does attempt to include Se in the groundwater reservoir.

Characteristics and Timing of Selenium's Release as Drainage: Source Waters

Mobility of Selenium: Source Flow, Concentration, and Load

The behavior and speciation of Se, and hence its solubility and mobility, are determined by a combination of processes including inorganic (e.g., weathering of the Coast Ranges) and organic (e.g., oxidation by bacteria) reactions. Oxidative reactions are partly responsible for Se mobility from source geologic formations of the Coast Ranges and the adjacent derived alluvial fans of the SJV (Figure A7) (Presser et al., 1990; Gilliom et al., 1989; Presser, 1994b). Selenium is oxidized to selenate, a form readily soluble in water and hence mobile in aqueous systems, as a function of oxygen flux or availability of oxygen and/or water in weathered rocks and soils. As oxygen saturation is reached, the rate of reaction may approach a constant value and Se remains in its highest oxidation state (i.e., +6, $SeO_4^{=}$) (Figure A7). Source agricultural drainage waters are selenate-dominated, a fact of major significance in determining the mobility of Se in surface water and groundwater systems and, hence, the extent and impact of Se in drainage water discharges (e.g., subsurface drainage) from those systems.

The effect of the large reservoir of Se on recent subsurface drainage flow (i.e., potentially discharged source waters) is illustrated in Figure A8. Figure A8 is generalized from data collected (USBR et al., 1999) during frequent sampling of drainage source water (i.e., current agricultural discharges to the SJR in WY 1997 and 1998 from the Grassland subarea). Flow or discharge increases with increased water flux (i.e., applied irrigation or precipitation). The concentration of Se in the discharged source agricultural wastewater increases as water flux increases. Only at elevated water fluxes seen during extremely wet years (i.e., the maximum rainfall occurring in a February over a 50-year record) does a dilution effect occur, lowering the concentration. The higher concentrations of Se discharged under high flow conditions are an indication of the magnitude of the Se reservoir and the conditions under which displacement of variable-quality shallow ground water may occur. Selenium load in source water also increases as a result of increased water flux (Figure A8). The combined effect of increasing concentration and increasing flow as water flux increases assures an increase in Se load discharged as more irrigation water is applied or more precipitation falls.

Control and Timing

The highest annual loads from agricultural drainage in the SJV (Figures A9) are discharged in years of normal or above average precipitation (CCVRWQCB, 1996b; c; 1998d; e; f; g; h; 2000b; c; CDWR, 1986-1998) (Figure A10) (also see later discussion). Regulatory load targets also are highest during February, March, April, and May, reflecting agricultural practices (Figure A11) (USBR, 1995; CCVRWQCB, 1996c; 1998a). It is possible that dilution afforded during wetter years by the increased volume of water in rivers could decrease salt and Se concentrations at compliance points in the SJR, or especially in the Bay-Delta, seaward from the inflows of the Sacramento River. The extent of dilution depends upon clean water inputs relative to SJR loads. Se and salt concentrations do not necessarily decrease in wet years in agricultural drainage water itself, or in agricultural drainage canals where discharge is predominantly Se-laden water. An out-of-valley agricultural drainage discharge to the Bay-Delta also may be subjected to these natural or seasonal effects (see later discussions on modeled discharge to the SJR). The effect could be larger loads to receiving waters during wet seasons than might otherwise be expected through management.

Control of release of agricultural discharge to take advantage of the high-volume river flows was suggested in 1955, when the SLD was planned and throughout many of the later planning reports (e.g., SJV Interagency Drainage Program, 1979a; b). Recently, the SWRCB Draft Environmental Impact Report (DEIR) for Implementation of the 1995 Bay-Delta Water Quality Control Plan concluded that scheduling the release of subsurface agricultural drainage from the western SJV is crucial to meeting the Bay-Delta water-quality standards including salinity (CSWRCB, 1997). Further documentation in the DEIR of future drainage systems conceptualizes the temporary control of drainage discharges stored in the soil profile using a system of valves, weirs, and sumps. A similar management technique using "DOSIR" valves is in practice in the Grassland subarea to enable storage of subsurface drainage [Grassland Area Farmers (GAF), 1997; USBR et al., 1999]. Grassland area farmers in discussions with regulators have pointed out the effect of this type of storage technique by calculating the amount of Se they *have not discharged* to the SJR on an annual basis (e.g., WY 1997, 3,680 lbs Se not discharged compared to 7,097 lbs Se discharged) (USBR et al., 1999). These types of drainage management activities emphasizes the importance of the consideration of the reservoir of Se and of documenting the Se inventory as opposed to focusing on short-term averages of discharges representing annual leaching to sustain a year-to-year farming effort.

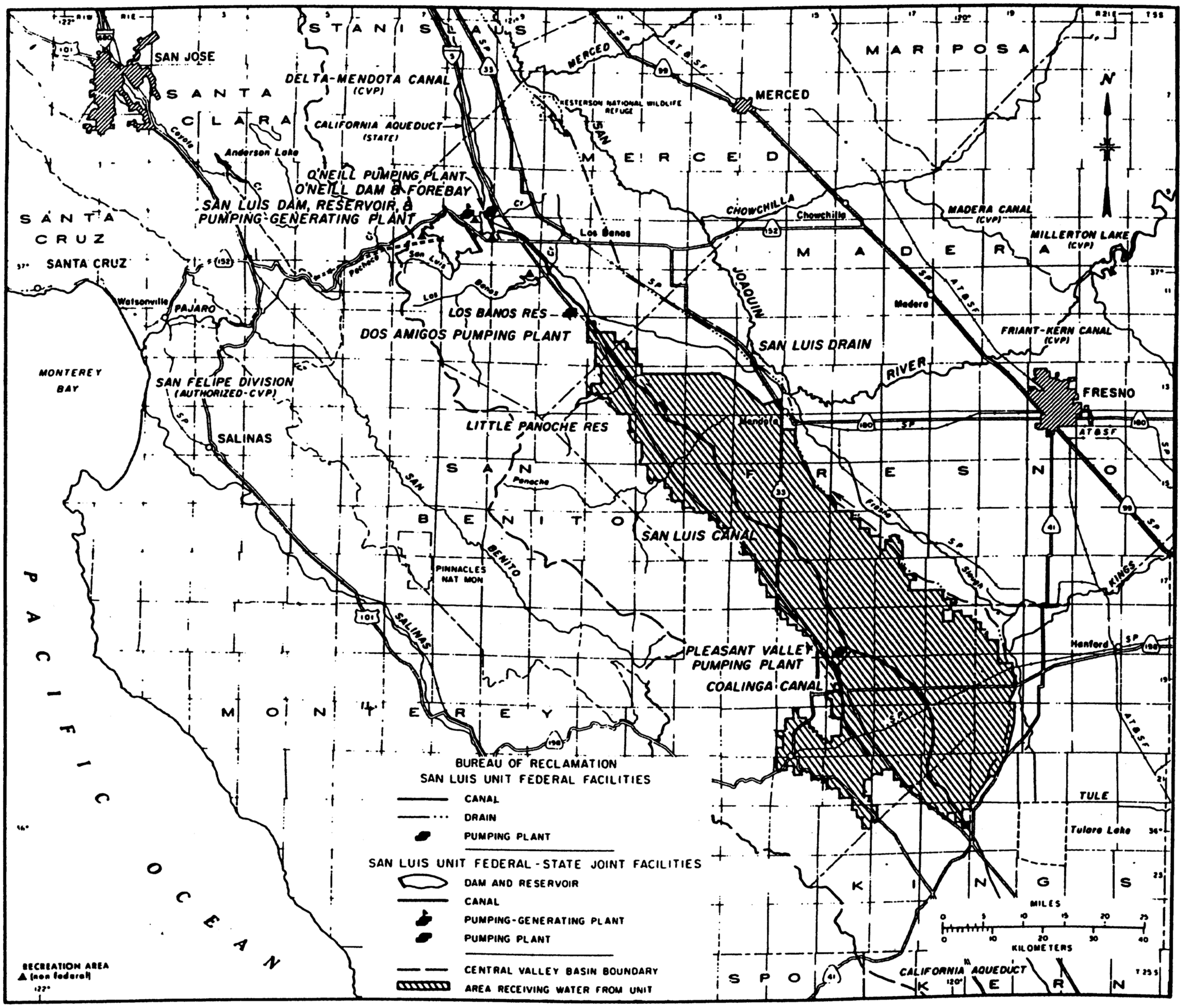

Figure A1. Map of San Luis Unit of the Central Valley Project (USBR, 1981).

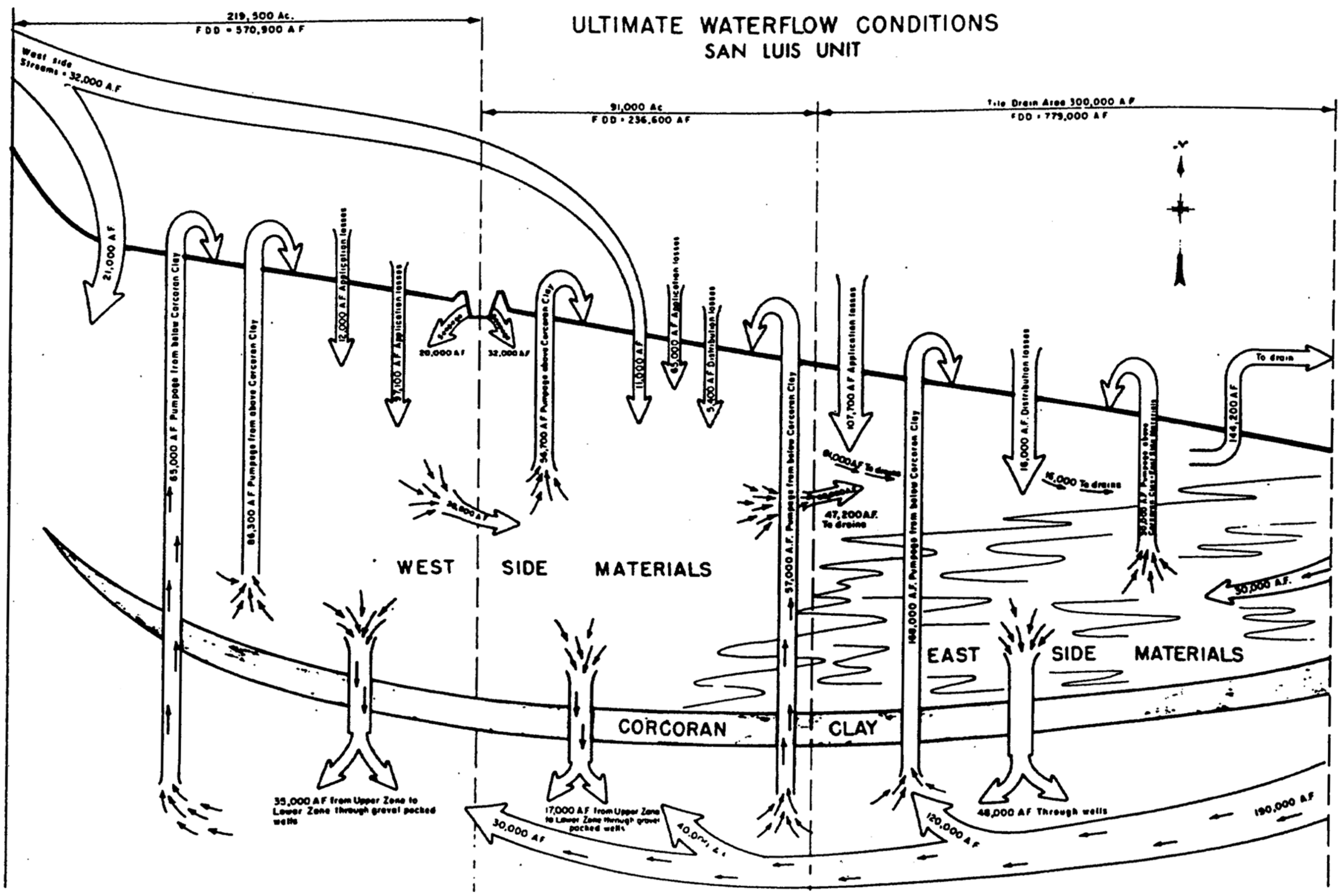

Figure A2. Schematic of "Ultimate Waterflow Conditions" of the San Luis Unit (USBR, 1978).

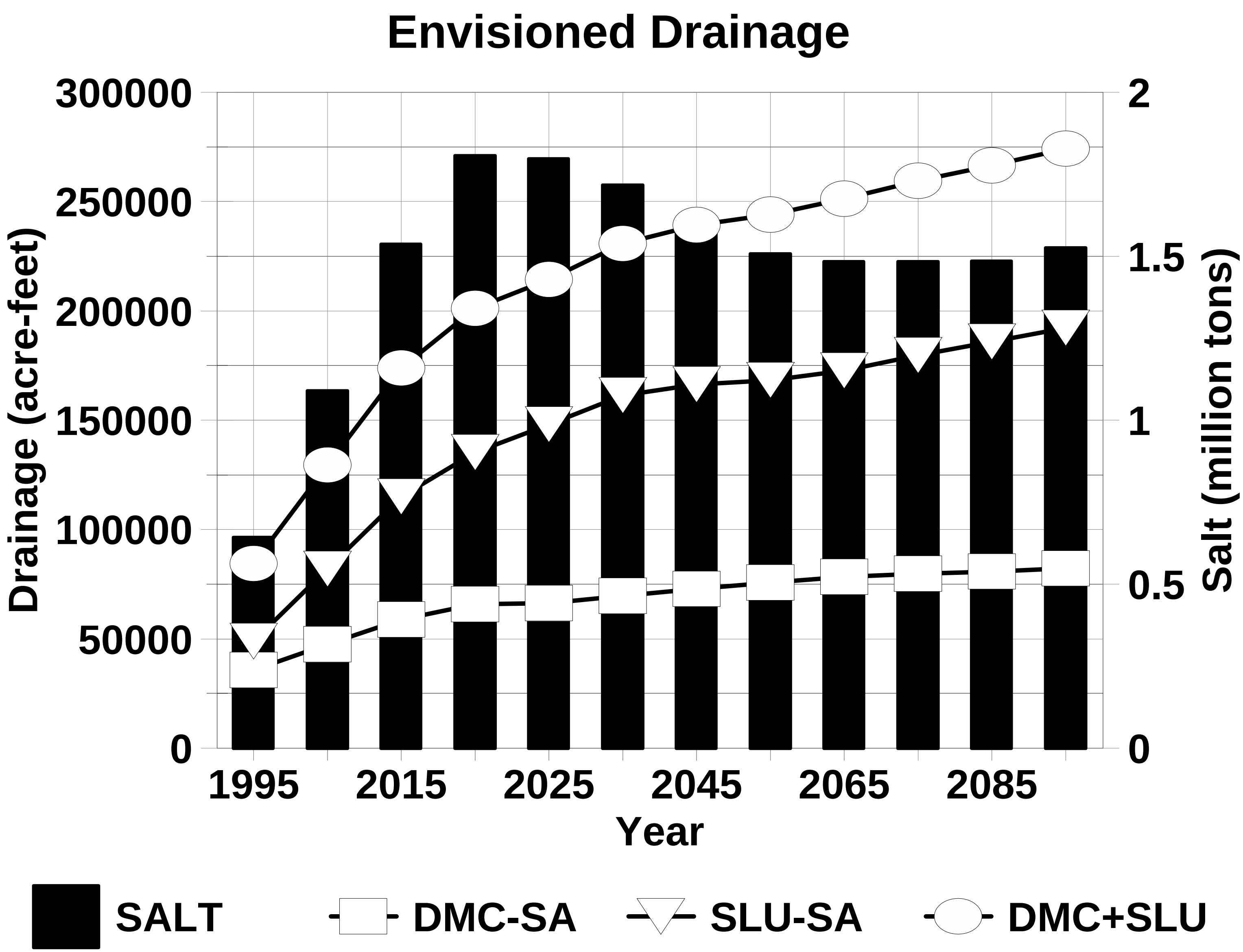

Figure A3. Envisioned salt discharges and drainage volume from the San Luis Unit to the San Luis Drain during the period 1995 to 2095 (USBR, 1983).

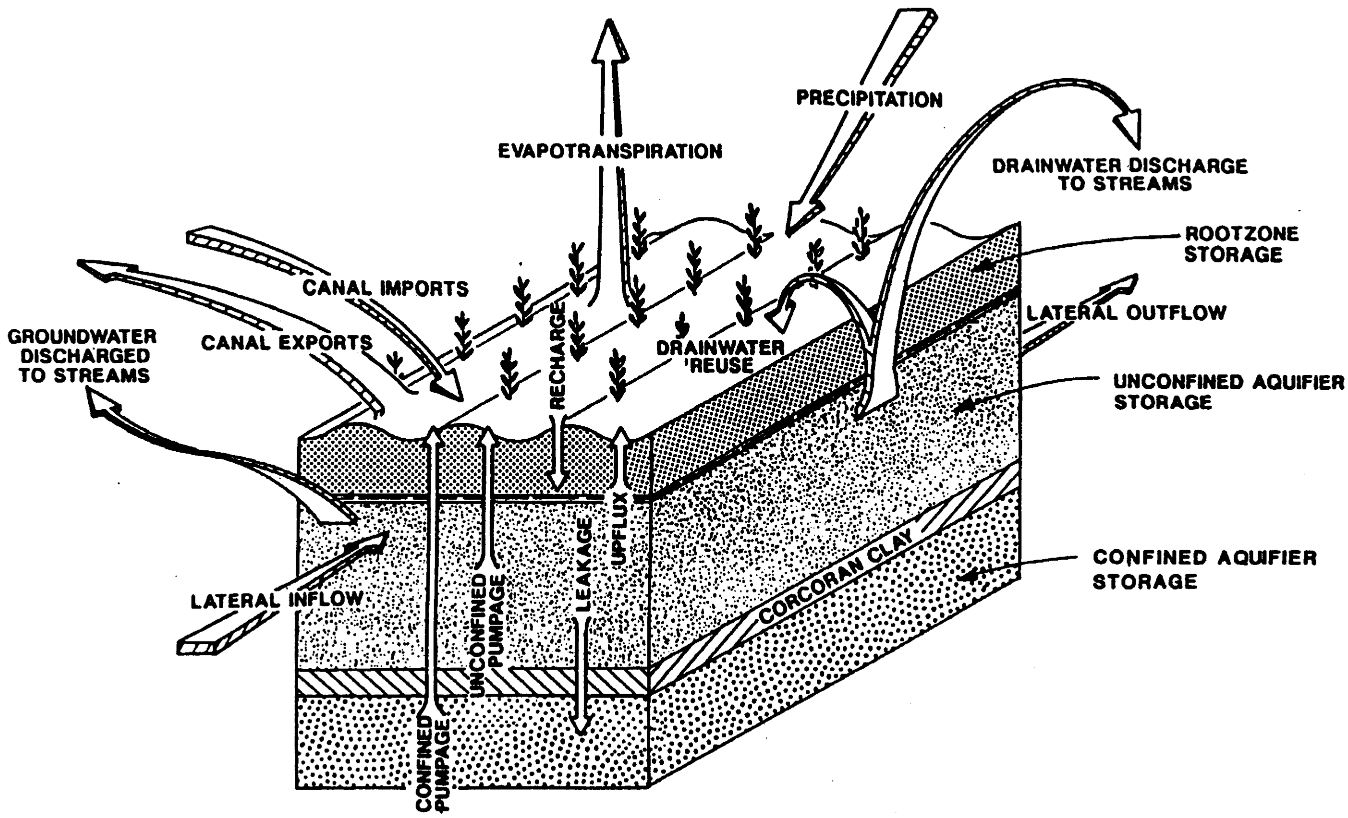

Figure A4. Conceptual water budget for the western San Joaquin Valley (USBR, 1989; adapted from CH2MHILL, 1988).

Figure A5. Surface water salt inflow/outflow (railroad cars per day) from the western San Joaquin Valley (printed with permission, SJV Drainage Implementatin Program, 1998).

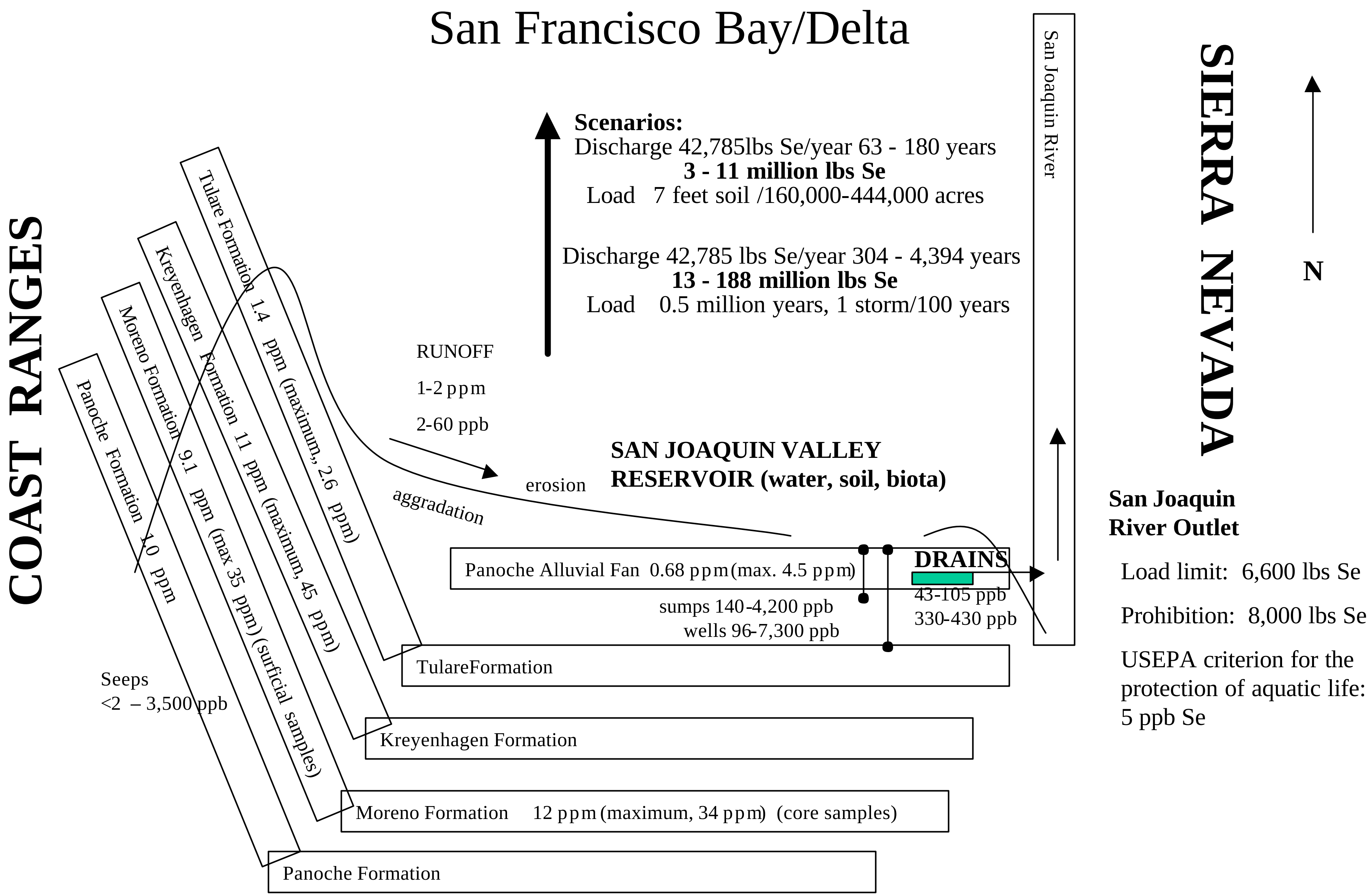

Figure A6. Schematic of selenium sources of the Coast ranges and the reservoir of selenium within the western San Joaquin Valley
If the discharge rate from the valley is assumed at approximately 42,500 lbs per year, then loading to the Bay-Delta could take place for 63 to 304 years, at the lower range of reservoir projections (see Tables A2 and A4). Data compiled from Presser et al., 1990; Presser and Piper, 1998; and this report.

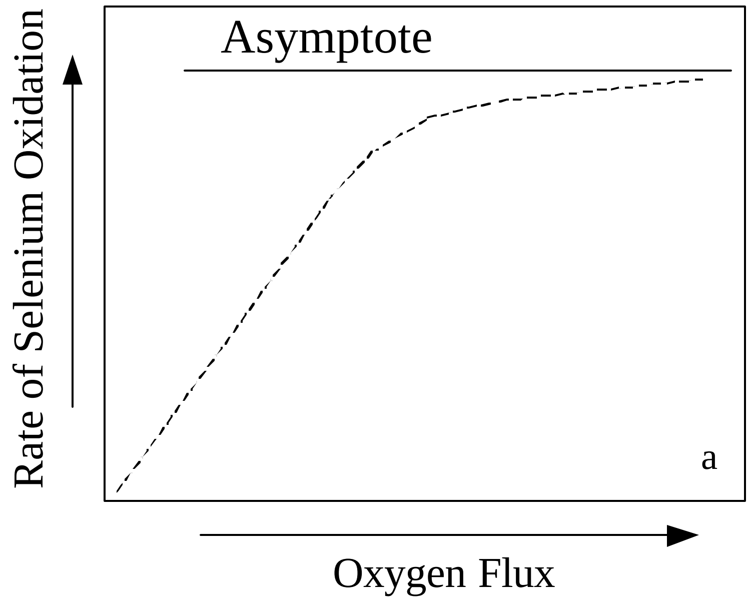

Figure A7. Schematic of selenium oxidation rate as a function of oxygen flux.

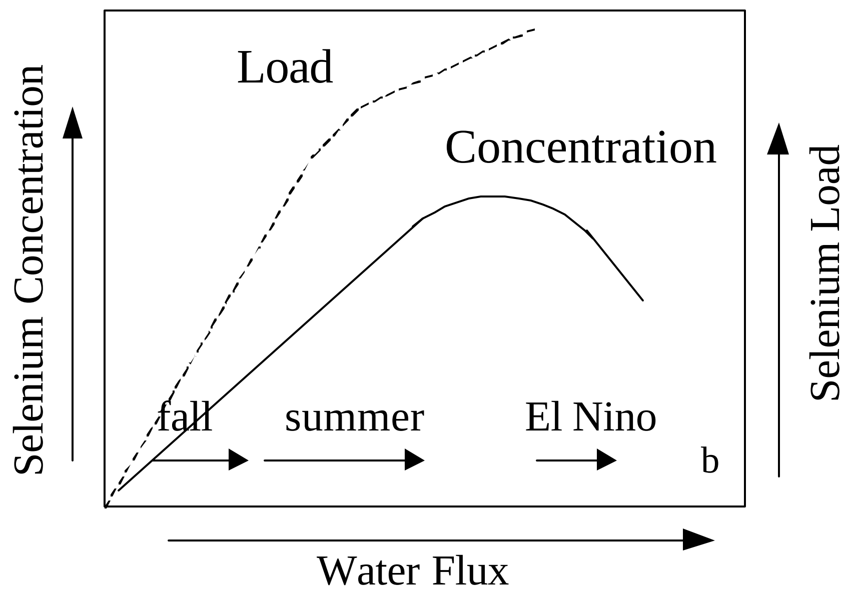

Figure A8. Schematic of selenium load and selenium concentration as a function of water flux.

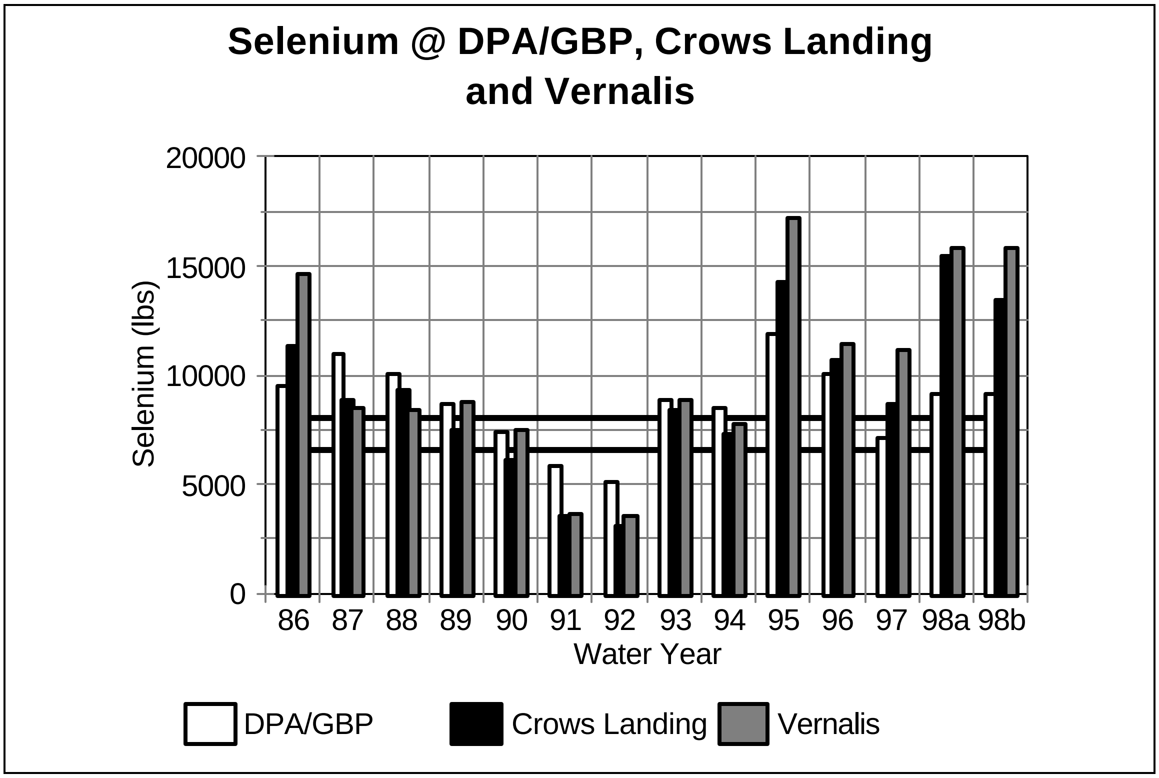

Figure A9. Selenium load (lbs) for Drainage Problem Area (DPA)/ Grassland Bypass Project Area, Crows Landing, and Vernalis for WY 1986 through WY 1998a and 1998b. Lower bar represents 6,600 lbs selenium. Upper bar represents 8,000 lbs selenium

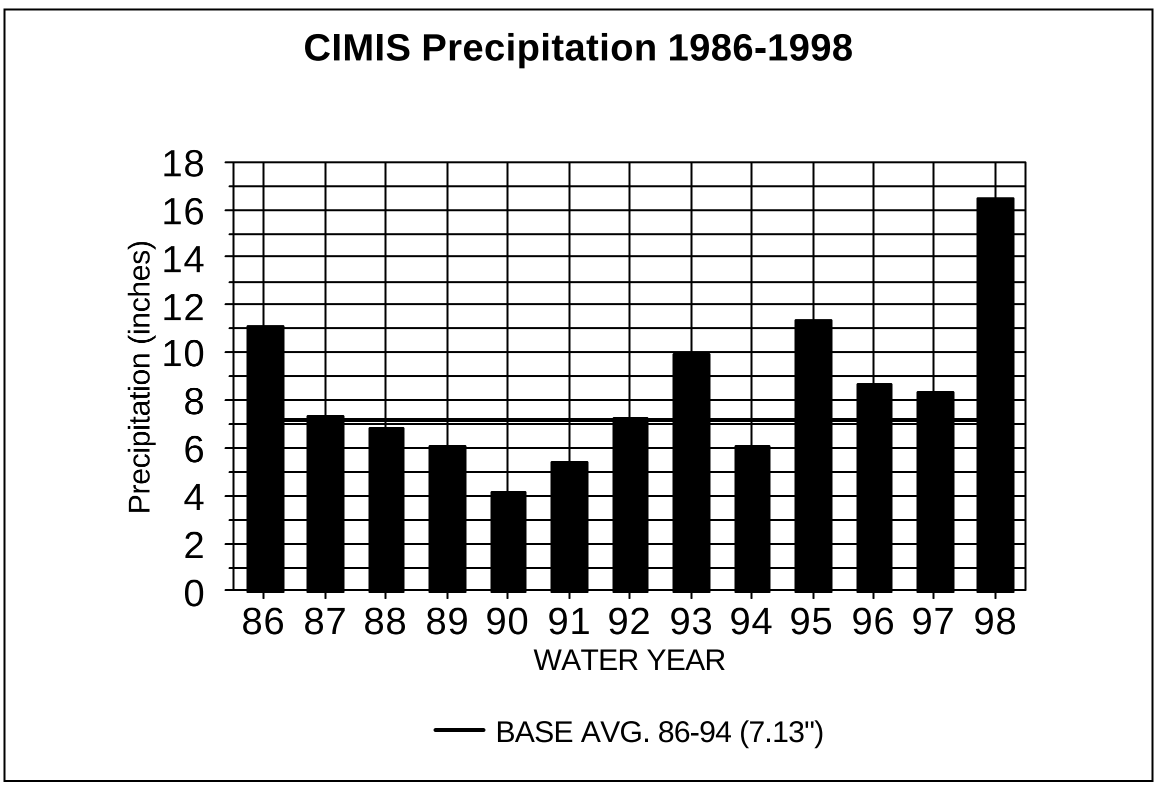

Figure A10. CIMIS (California Irrigation Management Information System) station # 124 precipitation for WY 1986 through 1998. Base average for 1986 to 1994 is 7.13 inches.

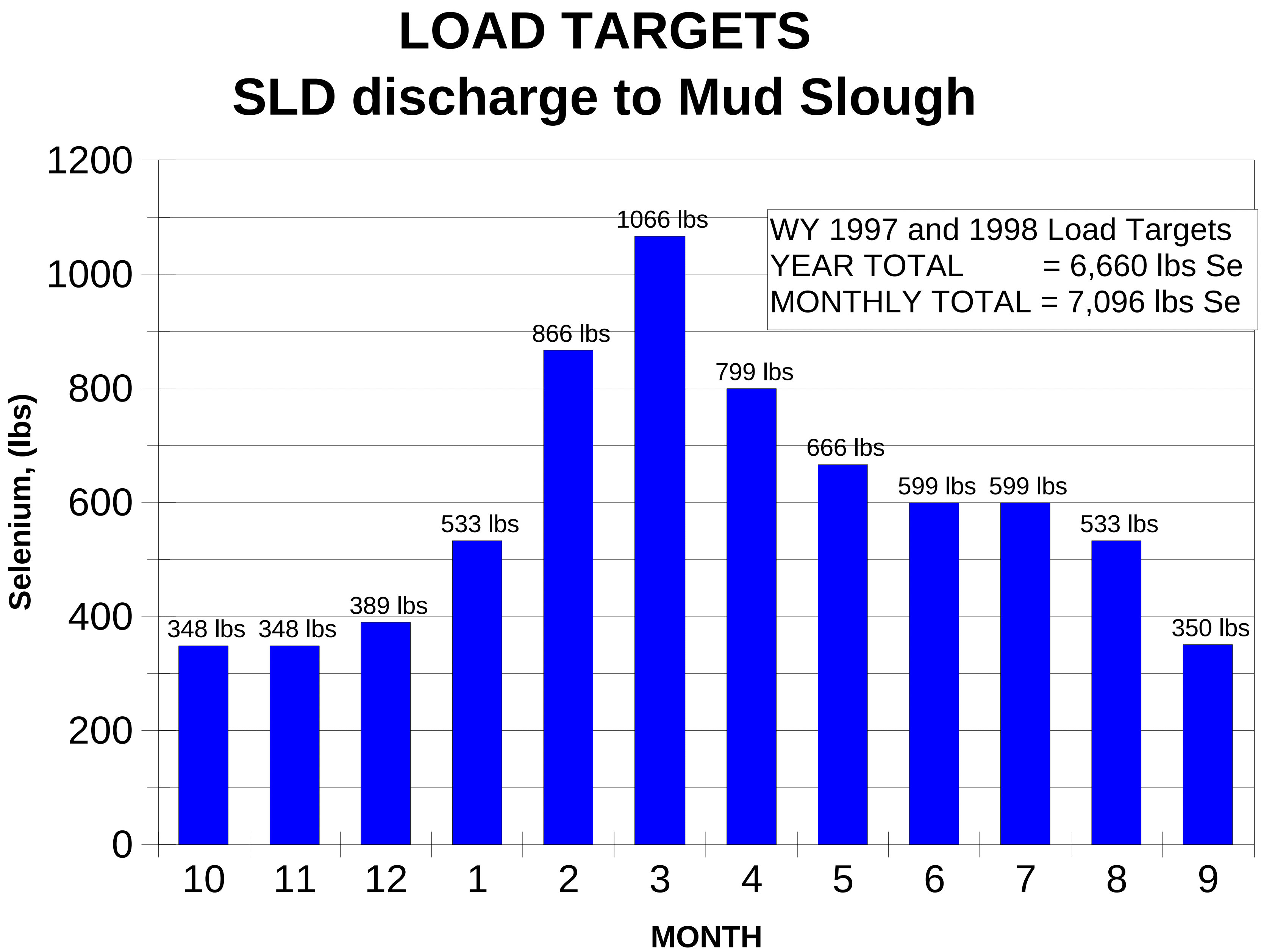

Figure A11. Monthly selenium load targets (lbs) for SLD discharge to Mud Slough for WY 1997 and 1998.

Table A1 Historical (USBR, 1978) prediction of drainage from San Luis Unit (San Luis Service Area and the Delta-Mendota Service Area). The ultimate or maximum condition is drainage of 300,000 acres.

	SJV Interagency Drainage Program 1975 estimated **acre-feet/year**	USBR 1977 estimated **acre-feet/year**	USBR modeled* **tons salt/year**
1980	20,000	3,100	43,710
1985	-	8,700	159,210
1990	47,000	19,000	317,300
2000	64,000	33,100	521,400
2010	71,000	107,400	1,385,460
2020	78,000	152,300	**1,538,230**
2030	88,000	154,100	1,094,110
2040	98,000		
2050	107,000		
2060	114,000		
2070	122,000		
2080	129,000		
Ultimate	150,000		

* Model predictions verified by sampling and analyses of drainage waters (USBR, 1978)

TABLE A2 Forecast selenium reservoir in San Joaquin Valley based on soils of the Panoche Fan.

Panoche Creek Alluvial Fan Soils Scenario	Acreage	Depth Meters*	Density grams/ cm2*	Soil Se** (ppm)	**Reservoir Million lbs Se (M lbs Se)**	**ksts (17,400 lbs Se = 1 kst)**	**Assumed removal rate 42,785 lbs Se/year*** (*see **Table 5** or generalized 314,000 AF@50 ppb)	**Years of loading to Bay/Delta**
Problem acreage (SJVDP, 1990a)	444,000	2 (6.6 feet)	2.0	0.68	**10.8**	**621**	42,785 lbs/year (0.043 M lbs/year)	**252**
	444,000	2	1.46	0.68	**7.7**	**442**	42,785 lbs/year (0.043 M lbs/year)	**180**
	444,000	15 (50 feet)	1.46	0.68	**59**	**3,391**	42,785 lbs/year (0.043 M lbs/year)	**1,379**
	444,000	91 (300 feet)	1.46	0.68	**356**	**20,460**	42,785 lbs/year (0.043 M lbs/year)	**8,321**
Panoche Fan Acreage*	160,000	2	1.46	0.68	**2.7**	**155**	42,785 lbs/year (0.043 M lbs/year)	**63**
	160,000	15	1.46	0.68	**20.3**	**11,667**	42,785 lbs/year (0.043 M lbs/year)	**474**
	160,000	91	1.46	0.68	**123**	**7,069**	42,785 lbs/year (0.043 M lbs/year)	**2,875**

*Bull, 1964
** Tidball et al., 1986; 1989

TABLE A3. Forecasts of Se generated during storms of WY 1998 for Panoche Creek. Storm runoff for WY 1998 was measured for Panoche Creek at highway I-5 by USGS (USGS, 1999; Kratzer et al., in press). Historic data for Se loads for Panoche Creek have not been previously available. Sampling was done during the storms of WY 1998 on a limited basis (Kratzer et al., in press). Extrapolations have been made here using the integrated area under the hydrograph for WY 1998. Loads measured for WY 1998 may represent maximum infrequent loading via Panoche Creek rather that being representative of annual historic loading (see text for more details). The forecast Se loads for WY 1998 form the basis of one of the forecasts of the Se reservoir in the western San Joaquin Valley (see Table A4, one large magnitude storm per 10, 50 or 100 years). Flow data with asterisks are approximated from gage height measurements making load values generated from these flows also approximate. Loads for WY 1997 are given for comparison. Storm runoff from Panoche Creek for WY 1997 was measured at the San Luis Drain inflow by Grassland Area Farmers (USBR et al., 1998).

Storm	hours	cfs (cubic feet per sec) start	cfs (cubic feet per sec) maximum	cfs (cubic feet per sec) end	Dissolved Se lbs	Suspended Se lbs	Total Se lbs
WY 1998							
February 3-4, 1998	34.8	310	8,000	750	640	3,850	4,490
February 6-7, 1998	28	1,800	2,800	200	179	699	878
February 8, 1998			6,500*				1,800
February 19-20, 1998			1,600*				250
February 21-22, 1998	28.5	2	1,400	220	76	236	312
February 23-24, 1998	21.8	510	2,100	180	67	248	315
SUBTOTAL WY 1998 (measured storms)					**962 (16%)**	**5,033 (84%)**	**5,995**
TOTAL WY 1998 (all storms)							**8,045**
WY 1997							
February 25, 1997							137
TOTAL WY 1997							**137**

TABLE A4 Forecast selenium reservoir in San Joaquin Valley based on storm runoff from Panoche Creek (see **Table 3A** for data used for extrapolation).

Panoche Creek Alluvial Fan Deposition and Recharge Scenario	**million lbs Se TOTAL (dissolved plus suspended)**	**million lbs Se DISSOLVED (dissolved-16% of total)**	**million lbs Se SUSPENDED (suspended-84% of total)**	**ksts (17,400 lbs Se = 1 kst) (range)**	**Assumed Removal Rate M lbs Se/ year (see Table 5, 42,785lbs/year)**	**Years of loading to Bay-Delta (range based on total Se)**	**Minimum years of loading to Bay-Delta (based on dissolved Se)**
0.5 million years 1 large magnitude storm year/10 years TOTAL	345-535	55-86	290-449	3,161-30,747	0.043	8,064-12,504	1,285
0.5 million years 1 large magnitude storm year/50 years TOTAL	140-387	22-62	118-325	1,264-22,241	0.043	3,272-9,045	514
0.5 million years 1 large magnitude storm year/100 years TOTAL	80-188	13-30	67-158	747-10,804	0.043	1,870-4,394	304
1.1 million years 1 large magnitude storm year/10 years TOTAL	759-1,177	121-188	638-989	6,954-67,644	0.043	17,740-27,510	2,828
1.1 million years 1 large magnitude storm year/50 years TOTAL	240-499	38-80	201-420	2,184-28,678	0.043	5,609-11,663	888
1.1 million years 1 large magnitude storm year/100 years TOTAL	175-415	28-66	147-348	1,609-23,850	0.043	4,090-9,700	654

APPENDIX B

San Joaquin Valley Agricultural Drainage Projections

APPENDIX B

San Joaquin Valley Agricultural Drainage Projections

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APPENDIX B

San Joaquin Valley Agricultural Drainage Projections

Projected Loadings from Historic Data and Evidentiary Testimony

Envisioned drainage volumes were presented in earlier discussions concerning the sustainability of discharge from the SJV and the conditions of water-quality in ground- water aquifers (Appendix A). Presented here are projections for the Westlands, Grasslands, Tulare, Kern, and Northern subareas based on limited available measurements of drainage discharge and planning estimates.

<u>Westlands Water District and Subarea</u>

Projections from Historic Data

Westlands subarea projections are based on limited historic measurements of drainage discharge from WWD into the SLD from 1981 until closure of the SLD in 1986 and planning estimates used in hearing testimony by WWD. Using a historical range of 330 to 430 µg Se/L concentration, the Se load from the initial hook-up of subsurface drains to the SLD during 1981 through 1985 was 6,283-8,187 lbs Se annually (Table B1). These amounts are higher than those estimated in the USBR Kesterson Program 1986 Environmental Impact Statement (EIS) as having occurred over the 57-month period of SLD operation (January 1981-September 1985, average of 4,776 lbs Se/year) (USBR, 1986). A recent compilation from WWD indicates a discharge of 38,450 acre-feet from January 1981 through May 1986 (WWD, 1998). The estimate of the total amount of Se discharged to Kesterson Reservoir from 1981-1985 was 22,660 lbs (USBR, 1986). The estimated input of Se includes 17,400 lbs that were distributed in the water, biota, and sediment of Kesterson Reservoir and 5,280 lbs of Se contained in 95,271 cubic yards of bed sediment still residing in the SLD. Selenium transferred from the seleniferous agricultural drainage water-column to the sediment contributed to the Se load remaining in the bed sediment. The 17,400-lbs amount is hereafter referred to as one kesterson (kst). This amount represents a unit of measure of potential cumulative hazard to wildlife based on load directly released into an ecosystem (Presser and Piper, 1998). It will be used later for comparison to provide a historical perspective.

Projections from Evidentiary Testimony

Evidence presented in 1996 referred to estimates prepared in 1965 for planned discharges from WWD, before emphasis was placed on efficient on-farm water management in the 1980's (WWD, 1996). Table B1 shows the planned discharge in 1980 in comparison to the Se loading estimated to have occurred from 1981 to 1985. The 1980's plans were expressed as volumes of drainage or acreage to be drained. If the 330-430 μg Se/L concentration range is used in conjunction with estimates of 38,000 acre-feet of annual drainage discharge, then plans were for discharge of 34,109-44,445 lbs Se/year from 76,000 acres in WWD (WWD, 1996). Using these estimates, the amount of drainage generated per acre is 0.50 acre-foot/acre. Calculated amounts of Se per acre (0.449-1.02 lbs Se) or acre-foot (0.898-1.17 lbs Se) for the planned drainage are also given in Table B1.

Since the closure of the 85-mile segment of the SLD in 1986, WWD drainage waters have been stored in the subsurface (Jones and Stokes, 1986a; b; SJV Drainage Program, 1989; 1990a). Data for Se concentrations in drainage presently are not available. The quality of the ground water is endangered by such practices, of course. The eventual loss of use of the groundwater basin beneath the SLU has been predicted at various stages of the planning process as a justification for the out-of-valley drain. Trade-offs were to be among lands kept in production, water export from the Bay-Delta, ground-water quality, and SJR degradation (USBR, 1978). The SJV Drainage Program in 1990 estimated the remaining life of the semi-confined aquifer beneath the Westlands subarea (576,000 acres) at a mean of 110 years (aquifer water-quality greater than 2,500 ppm TDS at a thickness of from 150 to 220 feet at current pumping rates). Minimum life remaining in some areas of the western SJV was as low as 25 years.

Several evidentiary proceedings concerning the disposition of drainage from WWD and the SLU have resulted in judgments and testimony concerning the quantity of drainage (Table B2) (WWD, 1996). Annual drainage discharge from the SLU of the CVP was estimated as part of the Barcellos decision (1986) to be an amount of discharge not greater than 100,000 acre-feet and not less than 60,000 acre-feet (USBR, 1992). Using assigned Se concentration of 50, 150, 300 μg Se/L, the amount of annual loading from the SLD would range from 8,160-81,600 lbs Se/year (Table B2).

Estimates presented in testimony in 1996 of drainage from WWD include 42,000 acres in the northeastern corner of WWD, where subsurface drains have been installed but are not connected to the SLD. The evidence stated that an additional 29.5 miles of SLD will be constructed to reach this area if drainage is to be provided for all areas of WWD needing drainage. Data for the annual volume of drainage (1,900-2,300 acre-feet) to be discharged upon initial reconnection to the SLD from WWD is not well justified, but is presented for comparison to those estimates given by WWD in 1980 (i.e., 7,000 acre-feet/year). The evidence presented shows a total problem acreage of 200,000 acres for WWD, with 60,000 acre-feet of drainage generated annually (WWD, 1996). This estimate represents a 0.3 acre-feet/acre rate of generation of drainage. Using assigned Se concentrations of 50, 150, and 300 μg Se/L, projected Se loads of 8,160 to 48,960 lbs Se/year were calculated for WWD, with an initial hook-up contributing 258 to 1,877 lbs Se (Table B2).

Grassland Subarea (WY 1986-1996)

Projections from Historic Data

Although provision of a drainage outlet was initially focused on WWD, parts of the Grassland subarea are within the SLU for which drainage is required (USBR, 1992). The larger historical area of the Grassland designated for the SLU is referred to as the Delta-Mendota Service Area (i.e., irrigation service from the Delta-Mendota Canal) as opposed to the San Luis Service Area (i.e., irrigation service from the San Luis Canal portion of the California Aqueduct). Essentially, the Grassland problem area considered here contains approximately 50,000 acres with a subsurface drainage system in a total of 100,000 acres in production. The area generates a blended subsurface drainage for discharge to the SJR. The SJV Drainage Program zones within the Grassland subarea are mainly based on water quality: zone A, 72,000 acres; Zone B, 14,000 acres; and Zone C, 30,000 acres (Table B3) (SJV Drainage Program, 1990a). Zone A generates drainage of poor enough quality to impair state beneficial uses of receiving waters and therefore is the focus for drainage analysis. The water and drainage districts of the Grassland subarea continue to consolidate into regional groups based on varying needs and legal ramifications, adding to the already complex historical alignments (USBR, 1992; Environmental Defense Fund, 1994).

The Se discharge to the SJR from the state-designated Grassland Drainage Area has been monitored since 1986 and is continuing currently (CCVRWQCB, 1996b; c; 1998 d; e; f; g; h; 2000b;c;

Henderson et al., 1995; USBR et al., 1998; 1999). Discharge occurred in the same configuration through the period 1986 to 1996 (drains to Grassland wetlands to SJR). Tables B4-B7 give summaries of the data for Se loads on a water-year basis from 1986 to 1998. An annual 8000-lb Se prohibition (CCVRWQCB, 1996c and 1998a) has been imposed by the state and an annual load target of 6,600 lbs Se for discharge to the SJR has been initiated by the USBR (1995) (also See Appendix A, Figure A9). The WY 1997 and 1998 Se loads measured further downstream in the SJR at Crows Landing is applicable to the state 8,000-lb prohibition limitation for Se discharge to the SJR effective October 1, 1996 (CCVRWQCB, 1998b). The Se load for the SJR at Crows Landing was 8,667 lbs Se in WY 1997 (CCVRWQCB, 1998h) and 15,501 lbs Se in WY 1998 (USBR et al., 1999).

Selenium is persistently discharged from the Grassland area to the SJR, but Se load values are dependent on the monitoring site location within the Grassland area (Tables B4-B7). The upstream drainage source discharge represents managed components of flow and load. Annual data are not available for individual farm-field sumps to represent source-area shallow groundwater conditions and thus show long-term variability in Se concentrations. The downstream sites reported here are the SJR at Crows Landing/Patterson (CL/PATT, approximately 50 miles downstream from the farm agricultural discharge sumps), and the SJR at Vernalis (VERN, approximately 130 miles downstream from the agricultural discharge). Data for WY 1986 to WY 1998 generally can be related to physical variables that affect drainage conditions (e.g., Appendix A, Figure A10, annual rainfall measured at station #124, compiled from CDWR database). Noted climatic changes during this time period are: drought from 1987 through 1992, flooding in the Coast Ranges in 1995, and flooding in the Sierra Nevada in 1997. Specific variables affecting Se load are discussed later in Appendix D.

Detailed analysis of loads for WY 1986 to 1988 reported an annual average of 10,850 lbs Se per year (Environmental Defense Fund, 1994). The range of annual loads for WY 1986 to 1998 for the managed source discharge is from 5,083 to 11,875 lbs Se/year (Table B4). For the same time period, the range of annual loads for the state compliance point for the SJR at Crows Landing is 3,064-15,884 lbs Se/year (Table B6). The range of loads for the SJR at Vernalis, the entrance to the Bay-Delta, from WY 1986 to WY 1998 is 3,558 to 17,238 lbs Se/year (Table B7). The higher loads in recent years are noteworthy because they occur after issuance of 1) state control plans for agricultural drainage issued in 1985 and 2) joint federal-state agricultural drainage management plans issued in 1990. Loads from the Grassland subarea have exceeded the annual 8,000-lb-prohibition for Se discharge to the SJR since its enactment in 1996. For WY 1986 through WY 1998, the cumulative Se load discharged to the SJR at Crows Landing/Patterson is 114,879 lbs Se (Table B6). This equates to 6.6 kestersons (ksts) as a measure of potential cumulative hazard based on load (see later discussion) (Presser and Piper, 1998). Of course, all sources, reservoirs, and discharges of Se are not known for the SJR system.

As described earlier, regulatory efforts through enactment of the TMML load allocation call for discharges of 1,001 to 3,088 lbs Se/year from the Grassland subarea, by the year 2010 (See Appendix C).

Grassland Bypass Channel Project (Reuse of the San Luis Drain, WY 1997 to present)

In 1990, the SJV Drainage Program considered re-routing drainage from the Grassland subarea through re-use of a portion of the SLD to avoid wetland contamination (i.e., drains to SLD to Mud Slough to SJR). Table B3 shows estimates by the SJV Drainage Program of potential drainage from the zones of the Grassland subarea. They assumed concentrations of 2 μg Se/L in both drainage from wetlands (Zone B) and in discharges from areas (Zone C). The discharge from the 72,000-acre Zone A was estimated at either 10,700 acre-feet containing a Se concentration of 150 μg Se/L or 21,000 acre-feet containing a Se concentration of 75 μg Se/L. The discharges from the entire Grasslands subarea was to be 4,524 lbs Se for year 2000 and 4,725 lbs Se for year 2040. These values are less than those measured for the recently initiated re-use of the SLD project described below (USBR et al., 1998 and 1999) for discharge from Zone C (37,500 acre-feet of drainage containing 62.5 μg Se/L from approximately 90,000 acres yielded 7,097 lbs Se in WY 1997, Table B8) and those measured historically (Tables B4 to B7).

Consideration of a project to re-open part of the SLD for use by the Grassland subarea was of enough concern to elicit a U.S. Congressional hearing in 1993 in Washington, D.C., as part of testimony on continuing agricultural drainage issues (U.S. House of Representatives, 1993). Although, environmental concerns were voiced, the interim-use project was seen as a way to relieve the pressure of a long-standing problem agricultural drainage problem in the SJV (U.S. House of Representatives, 1993). On September 23, 1996 a cooperative project among agricultural, government, and environmental parties was initiated by the USBR (1995), which reopened the SLD on an interim five-year basis. The drain transports drainage to the SJR and thereby removes it from wetland channels. Named the Grassland Bypass Channel Project (GBCP), the project focuses on the use of a 28-mile portion of the SLD to provide drainage for approximately 97,400 acres in the Grassland subarea. The Grassland Bypass Channel Project is a regional effort to improve water quality by regulating Se loads.

The goals include: 1) measuring and eventually reducing drainage loads through a regional program; 2) protecting riparian wildlife habitat by assuring the wetlands of an adequate clean-water supply; and 3) examining possible adverse effects that may result from the routing of drainage through the SLD and Mud Slough to the SJR. The GBCP contains commitments to meet and further define environmental concerns for wetlands and the SJR. A regional drainage agency that includes local water and drainage districts has been created and assigned responsibility for pollution. A federal/state interagency committee monitors flow, water-quality, sediment quality, biota and toxicity in the SLD, Mud Slough, Salt Slough, and the SJR (USBR et al., 1996). Monetary penalties for exceedance of loads have been agreed upon and a long-term management strategy to achieve water-quality objectives is being developed (GAF, 1998a).

The Se load targets for the reuse of the SLD are defined only by the commitment that the input loads to the SJR "will not worsen" over historical loads (USBR, 1995). Appendix A (Figure A11) shows the monthly load targets adopted for the first two years of Grassland Bypass Channel Project. Compliance loads are measured at the discharge of the SLD into Mud Slough rather than at the SJR at Crows Landing, as previously regulated by the state (CCVRWQCB, 1996c). In September 1998, a waste discharge permit was issued for the GBCP by the state (CCVRWQCB, 1998a), which contained the negotiated load targets. Tables B8, B9, and B10 show the annual and monthly load targets for 1997 through 2001. The target is 6,660 lbs for each of the first two years of the project with a 5% reduction each year for the next three years. Also shown is the state's prohibition of drainage discharge limitation for the SJR, which limits Se discharge to the SJR and tributaries to 8,000 lbs/year. If the annual target amount is exceeded by 20%, consideration would be given to shutting down the SLD and terminating the GBCP (USBR, 1995). The comparison of targets with measured loads shows that in neither year did the project meet the federal target, although loads in 1997 were lower than the state target. It is also notable that drain water discharged to the SJR through the SLD is more consistently concentrated than were the historic discharges to the wetlands channels system. The wastewater in the SLD is not diluted by wetlands flows, and loss of Se to sediment and biota, as occurred during transit through wetland channels (i.e., "in-transit loss"), may be reduced (USBR, 1995; Presser and Piper, 1998). Recent adoption by the state of a water-quality objective of less than 2 μg Se/L for the Grassland wetland channels as promulgated by USEPA (USEPA, 1992; CCVRWQCB, 1996c; 1998a), has essentially removed these channels as alternative flow paths for drainage water, however. This regulation will make it difficult to re-use the wetland channels, for example, as alternative channels during flood runoff or in the event that WWD once again uses the SLD.

Tables B9 and B10 give the detailed monthly data for the GBCP including volumes and Se targets, loads, and concentrations (USBR et al., 1998 and 1999). The annual load of 7,104 for WY 1997 includes 6,960 lbs Se that was discharged from the SLD and 137 lbs Se that was discharged to wetland channels during a flood in January 1997. A fee of $60,000 was paid by the Grassland Area Farmers for exceedances of the monthly and annual Se load targets by 437 lbs (6.6%) in the first year of the project. The annual load represents 0.073 lbs Se/acre or 0.189 lbs Se/acre-foot for the Grasslands Area of 97,400 acres. The average Se concentration in the discharge for WY 1997 was 62.5 μg Se/L and the total volume was 37,483 acre-feet. The annual load for the second year of the GBCP, WY 1998, was 9,130 lbs Se. The annual Se load target was exceeded by 37% which could have incurred a fee of $174,400 if the load was left unadjusted for flooding during the higher than normal rainfall in 1998 (note, 1998 was an El Nino year). The WY-1998 upper watershed load was estimated at 487 lbs Se, with 350 lbs documented in overflow to wetland channels. The average Se concentration in the discharge for WY 1998 was 67 μg Se/L and the total volume was 45,858 acre-feet. The annual load represents 0.094 lbs Se/acre or 0.199 lbs Se/acre-foot for the Grasslands Area.

<u>Westlands Subarea in Combination with Grassland Subarea</u>

An analysis by the USBR in 1983 showed a combined discharge for the SLU and Delta-Mendota Services Areas which includes the Grassland subarea. Taking the worst-case scenario for the year 2020, the amount of drainage from the SLU Service Area is 135,240 acre-feet and from the Delta-Mendota Service Area is 65,783 acre-feet. Using assigned concentrations of 50, 150, and 300 μg Se/L with these amounts of drainage, the range of Se discharged from SLU Service Area is from 18,393 to 110,356 lbs Se/year and for the Delta-Mendota Service Area is from 8,946 to 53,679 lbs Se/year. The range of total discharge is from 27,339 to 164,035 lbs Se/year.

Evidentiary hearings (WWD, 1996) also included a scenario in which the Grassland Area drainage being discharged to the SJR would be discharged to the SLD, along with the WWD discharges (although, under current agreements, the GBCP would terminate if WWD is given permission to use the SLD) (USBR, 1995). This additional drainage (30,000 to 40,000 acre-feet) is hypothesized to be of better quality than that of water discharged to Kesterson Reservoir. The additional load calculated using the measured average concentration (62.5 μg Se/L) for Grassland discharge for WY 1997 is

5,100-6,800 lbs Se/year (Table B2). Thus, the range for a total annual load from WWD and the Grassland Area discharged under this scenario to the SLD is 13,518-15,273 lbs Se/year, if WWD drainage contains a concentration of 50 µg Se/L. The loads increase to 30,355 to 32,218 lbs Se/year if WWD drainage contains a concentration of 150 µg Se/L, and 55,610 to 57,637 lbs Se/year if WWD drainage contains a concentration of 300 µg Se/L.

Projections from San Joaquin Valley Drainage Program Management Options

The data for acreage and drainage volumes used by the SJV Drainage Program for planning purposes for each of the five subareas is given in Tables B11 through B17. Two possible alternative futures were defined by SJVDP: 1) no implementation of the SJV Drainage Program management plan, 0.60 to 0.75 acre-feet/acre generated drainage, namely, *without future* and 2) with implementation of the SJV Drainage Program management plan, 0.40 acre-feet/acre generated drainage, namely, *with future* (SJV Drainage Program 1989 and 1990a). A third condition defined for use in our projections is called *with targeted future*. The *targeted future* condition applies a factor of 0.20 acre-feet/acre of generated drainage, exemplifying the lowest, although probably not realistic, irrigation water return. Like earlier plans, the SJV Drainage Program did not calculate concentrations of Se in drainage water, or Se loads directly, but rather focused on estimating the volume of drainage and the affected acreage for subareas. Assigning Se concentrations of 50, 150 and 300 µg Se/L to these volumes, gives the general magnitude of expected Se discharge or loading.

Table B18 gives the details of specific loadings from each of the five subareas based on the estimates given by the SJV Drainage Program for year 2000 and assigned concentrations of 50, 150, and 300 µg Se/L. This summary gives ranges of acre-feet of drainage and potentially discharged annual loads of Se for the assigned concentrations. Figures B1a, b, and c depict the ranges of agricultural discharges for assigned concentrations of 50, 150, and 300 µg Se/L if all subareas are considered discharging to a valley-wide drain. Considered on a subarea basis, the Se loads are (Table B18):

- *Northern subarea.* Discharge from the Northern subarea is to the SJR. The range of projections of annual Se loads for the Northern subarea is 925 to 3,536 lbs Se for an assigned concentration of 50 µg Se/L; 2,774 to 10,608 lbs Se/year for an assigned concentration of 150 µg Se/L; and 5,549 to 21,216 lbs Se/year for an assigned concentration of 300 µg Se/L.

- ***Grassland subarea.*** Discharge from the Grassland subarea is to the SJR. The range of projections of annual Se loads for the Grassland subarea is 2,938 to 11,696 lbs Se/year for an assigned concentration of 50 µg Se/L; 8,813 to 35,088 lbs Se/year for an assigned concentration of 150 µg Se/L; and 17,626 to 70,176 lbs Se/year for an assigned concentration of 300 µg Se/L.
- ***Westlands subarea.*** WWD (i.e, encompassing the Westlands subarea) is currently asking to extend the SLD to the Bay-Delta as a drainage outlet. The range of projections of annual Se loads for the Westland subarea is 1,877 to 11,016 lbs Se/year for an assigned concentration of 50 µg Se/L; 5,630 to 33,048 lbs Se/year for an assigned concentration of 150 µg Se/L; and 11,261 to 66,096 lbs Se/year for an assigned concentration of 300 µg Se/L.
- ***Tulare subarea.*** Tulare subarea currently discharges to privately owned evaporation ponds. The range of projections of annual Se loads for the Tulare subarea is 2,611 to 10,200 lbs Se/year for an assigned concentration of 50 µg Se/L; 7,834 to 30,600 lbs Se/year for an assigned concentration of 150 µg Se/L; and 15,667 to 61,200 lbs Se/year for an assigned concentration of 300 µg Se/L Se.
- ***Kern subarea.*** Kern subarea currently discharges to privately owned evaporation ponds. The range of projections of annual Se loads for the Kern subarea is 1,088 to 6,256 lbs Se/year for an assigned concentration of 50 µg Se/L; 3,264 to 18,768 lbs Se/year for an assigned concentration of 150 µg Se/L; and 6,528 to 37,536 lbs Se/year for an assigned concentration of 300 µg Se/L.

Projections from Currently Available Data

Tables B1, B2, B9, B10, B19, B20, and B21 give the derivation and details of specific loads projected from each of the five subareas based on our compilation of currently available data on problem acreage, drainage volume, and Se concentration. These data have become available since the SJV Drainage Program was completed in 1990. Depending on the type of data available from each subarea, projections were made concerning concentration and load. Because of the limited data and broad range of management alternatives across the subareas, maximum and minimum Se concentrations are given to bracket possible load scenarios given a specific volume of drainage for each subarea. The projected concentration range is 5 to 10 µg Se/L for the Northern subarea, 68 to 152 µg Se/L for Grassland subarea, 49 to 150 µg Se/L for Westlands subarea (note, no current data, only testimony on acreage is available), 1.7 to 9.8 µg Se/L for Tulare subarea, and 175 to 254 µg Se/L for

Kern subarea. Although site-specific in nature, these projections address only the present discharge to manage the annual imbalance and not general amounts of *problem water*. Projections for the five subareas are:

- ***Northern subarea***. Discharge from the Northern subarea is to the SJR. The projected concentration range is 5 to 10 μg Se/L for the Northern subarea. The Northern subarea minimum projection is based on a nominal 5 μg Se/L Se concentration applied to adhere to the USEPA promulgated Se standard for the SJR. Because management options were not recommended for the Northern subarea, the assumed drainage volume is that estimated by the SJV Drainage Program for year 2000 without implementation of the management plan alternatives (SJV Drainage Program, 1990a) (Tables B13 through B17). The range of projected annual Se loads for the Northern subarea is 350 to 750 lbs Se/year, if a maximum concentration of 10 μg Se/L is applied to the same drainage volume.
- ***Grassland subarea***. Discharge from the Grassland subarea is to the SJR. The projected concentration range is 68 to 152 μg Se/L for the Grassland subarea. The Grassland subarea projection is based on the Grassland Bypass Channel Project measured volume of discharge in WY 1997 (Tables B9 and B10). The projected Grassland subarea minimum load is 6,960 lbs Se/year. The projected Grassland maximum load is 15,500 lbs Se/year, a load similar to that measured for the SJR at Crows Landing in an extremely wet year (i.e., WY 1998). The maximum load attempts to represent a load that includes upstream SJR loads of Se and recycled Se loads from the Delta-Mendota Canal**.**
- ***Westlands subarea***. Westlands subarea (or WWD) currently recycles its drainage and therefore no discharge data is available. The projected concentration range is 49 to 150 μg Se/L for the Westlands subarea (note, no current data, only testimony on acreage is available). The WWD subarea minimum acre-feet discharge and load are for conditions presented as evidence for WWD (60,000 acre-feet at 49 μg Se/L Se, WWD, 1996) (Tables B1 and B2). The maximum load is based on a Se concentration of 150 μg Se/L (163 μg Se/L median and USBR conservative estimate of "at least 150 μg Se/L") applied to 60,000 acre-feet. The projected range of annual Se loads for WWD is 8,000 to 24,480 lbs Se/year.
- ***Tulare subarea.*** Tulare subarea currently discharges to privately owned evaporation ponds. The Tulare subarea projections are based on measurements for volume and Se concentration from 1993

to1997 (personal communication 1/98, Anthony Toto, CCVRWQCB). A compilation of available data from discharges in the Tulare subarea is given in Tables B19 and B20. Concentration and volume data for 1988, 1989, 1994, and 1996 are shown for comparison, although sets of data are not available in order to calculate load. An average volume is used in the projections in conjunction with the minimum and maximum Se loads. From the sparse data available from the Tulare subarea for 1993, 1995, and 1997, the projected concentration range is 1.7 to 9.8 μg Se/L. The range of projected annual loads for the Tulare subarea is 91 lbs to 519 lbs Se/year, with the majority of the discharge to the Tulare Lake Drainage District ponds. A main point of these calculations is to compare the magnitude of loading from subareas even in view of limited data. The projected annual Se load from this area is small relative to that projected from WWD and Grassland subareas, largely because the projected Se concentrations are low in managed drainage from the Tulare subarea.

- *Kern subarea.* Kern subarea currently discharges to privately owned evaporation ponds. A compilation of available data from discharges in the Kern subarea is given in Table B21. Kern subarea projections are based on measurements for volume and Se concentration from 1993 to1997 (personal communication 1/98, Anthony Toto, CCVRWQCB). An average volume is used in the projections in conjunction with the minimum and maximum Se loads. From the sparse data available, the projected concentration range is 175 to 254 μg Se/L for Kern subarea. Projected annual Se loads from the Kern subarea range from a total of 1,089 to 1,586 lbs. A main point of these calculations is to compare the magnitude of loading from subareas even in view of limited data. The projected annual Se load from this area is small relative to that from WWD and Grassland subareas, largely because the projected volumes of drainage are low from the Kern subarea.

A compilation of our projections based on currently available data is given in Table 7. Sets of graphs in Figures B2 and B3 compare generalized projections from SJVDP volumes (Table B18) with those based on currently available data (Table 7). The ranges of drainage volume and annual Se loads are presented graphically for each assigned concentration, i.e., 50, 150, and 300 μg Se/L for each subarea (Figures B2a through e). The ranges of projected drainage volumes and annual Se loads are presented graphically for the minimum and maximum concentrations derived from current data (Figures B3a through e). In general, this graphical technique enables a prediction or projection of an annual Se load for any assigned concentration or current condition given a specific drainage volume. Again, the ranges are due to varying estimates of predicted problem water and subsurface drainage under different management alternatives. The comparisons show the relative contribution of load from each subarea in the event that all subareas discharge into an SLD extension. The graphical technique also shows patterns of Se concentration and load that are indicative of the geology, hydrology, and chosen management options for each subarea.

Estimates of Capacity of Drainage Conveyance (i.e., proposed SLD extension)

As a final check of the magnitude of the load projections, the various design capacities of the SLD or a SLD extension are combined with assigned Se concentrations to calculate load (Table B22). The concentration is held constant to simulate a constant discharge from a constructed conveyance system as opposed to a seasonally impacted conveyance system such as the SJR. The SLD design capacity is projected at 300 cfs (as suggested as early as 1955 and recently) (USBR, 1955; 1962; 1978; CSWRCB, 1999a), which is equivalent to 216,810 acre-feet/year. At a concentration of 50 µg Se/L, the annual Se load is 29,486 lbs Se. Using an assigned concentration of 150 µg Se/L, the annual load to the Bay-Delta is 88,458 lbs Se. For a 300 µg Se/L discharge, the annual load is 176,917 lbs Se. Other historical estimates of annual discharge for the SLD (e.g. 144,200 acre-feet/year in early planning; 150,000 estimated during 1975-1977 for 50-100 years of drainage; and 84,525 to 279,270 acre-feet estimated in 1983 for the period 1995-2095) also can be used to estimate loads by applying assigned concentrations to discharge capacity. An estimate of drainage available from the SJV for discharge to the San Francisco ocean outfall showed 375,000 acre-feet annual drainage discharge and a 400,000 – 500,000 acre-feet capacity of a drainage facility (Montgomery-Watson, 1993). All of these estimates show a need for a drain of greater than 200,000 acre-feet/year.

Total flux from Agricultural Drainage Discharge (lbs Se/day)

It is also useful to present projected Se loading from the western SJV to the Bay-Delta in terms of rate of discharge (lbs Se/year and lbs/day) and in terms of cumulative load expressed in kestersons (ksts) (Presser and Piper, 1998). The kst unit is the cumulative total of 17,400 lbs Se, which when released directly into Kesterson Reservoir caused ecotoxicity and visible ecological damage. It is used here as a measure of potential ecological damage based on Se load. Table B23a shows that a projected

Se discharge from the western SJV to a SLD extension to the Bay-Delta based on generalized SJV Drainage Program data (i.e., 314,000 acre-feet of problem water with an assigned concentration of 50 μg Se/L, or 144,000-163,000 acre-feet of subsurface drainage with an assigned concentration of 150 μg Se/L) would be 2.4 to 3.8 ksts per year. The flux of Se discharge from the drain to the Bay-Delta is projected to range from 117 to 182 lbs Se/day. Tables B23b and B23c and Figures B4a and B4b show a projected Se rate of discharge (lbs Se/day) from each of the five designated subareas of the western SJV using the minimum and maximum scenarios defined earlier from currently available data (Figure B3). The range of Se flux from each subarea is: Northern, 0.95 to 1.9 lbs Se/day; Grassland, 19 to 42 lbs Se/day; Westlands, 22 to 67 lbs Se/day; Tulare, 0.25 to 1.4 lbs Se/day; and Kern, 3.0 to 4.3 lbs Se/day. The total Se flux is 45 to 117 lbs Se/day under the assumed conditions. The Westlands and Grassland subareas discharge the largest proportion of the daily annual load (Figures B4a and B4b). The range of combined loads from the Grasslands and Westlands subareas is 0.86 to 2.29 ksts/year. For comparison, the current prohibition limitation for the Grassland subarea to the SJR is 8,000 lbs/year or 0.46 ksts/year.

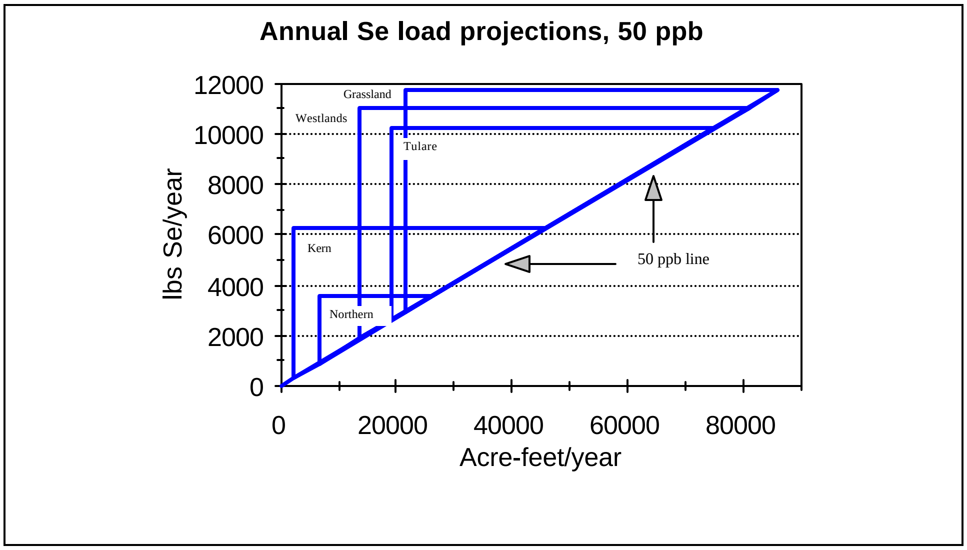


Figure B1a

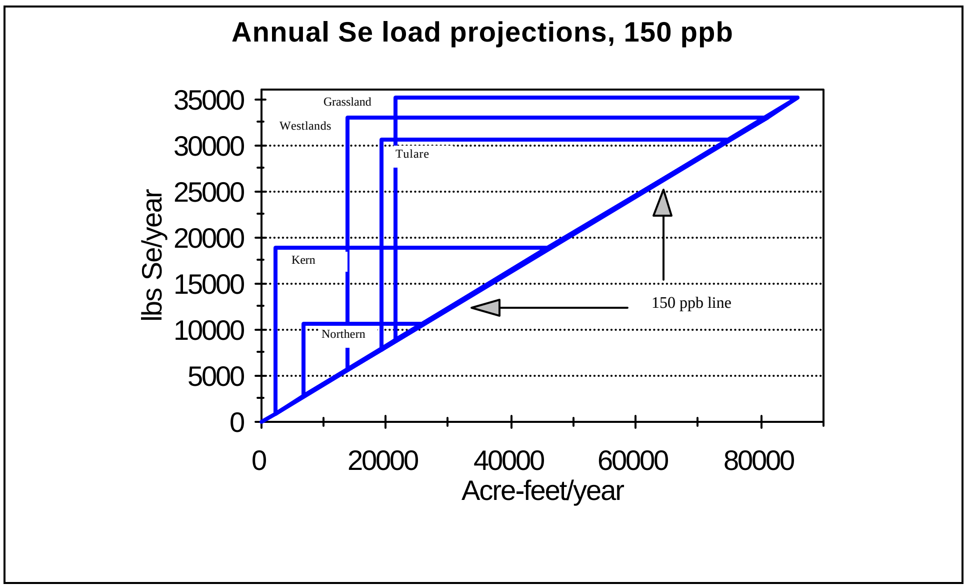


Figure B1b

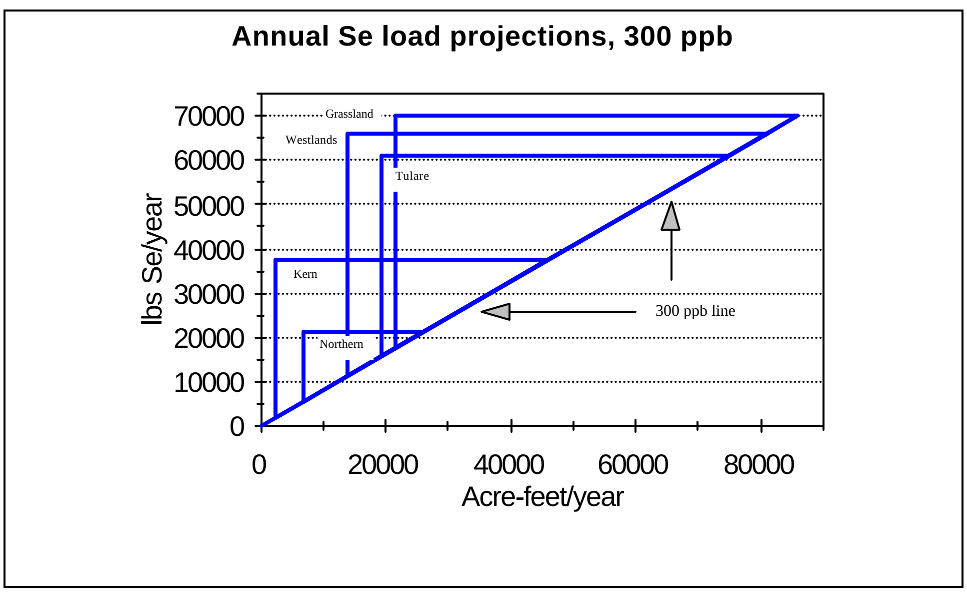


Figure B1c

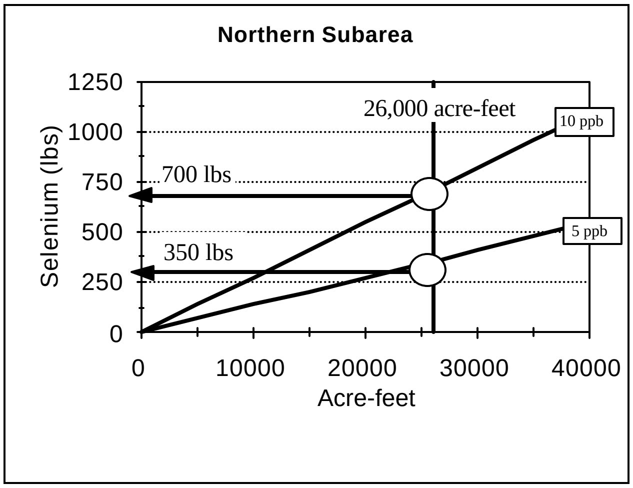


Figure B2a

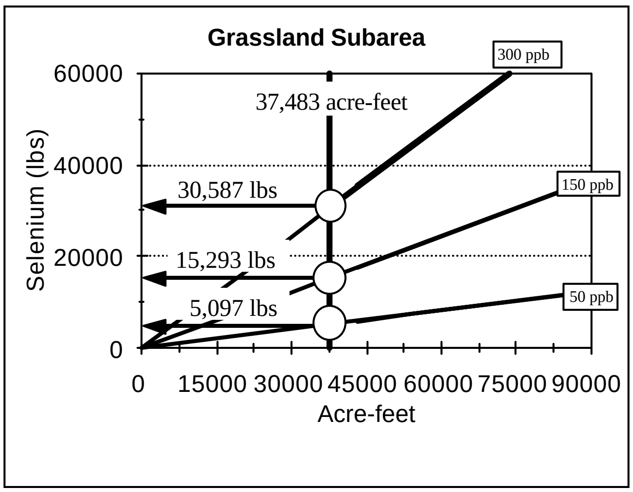
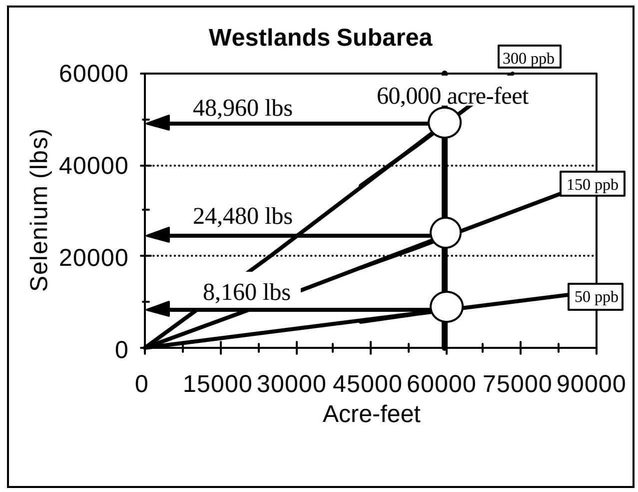


Figure B2b



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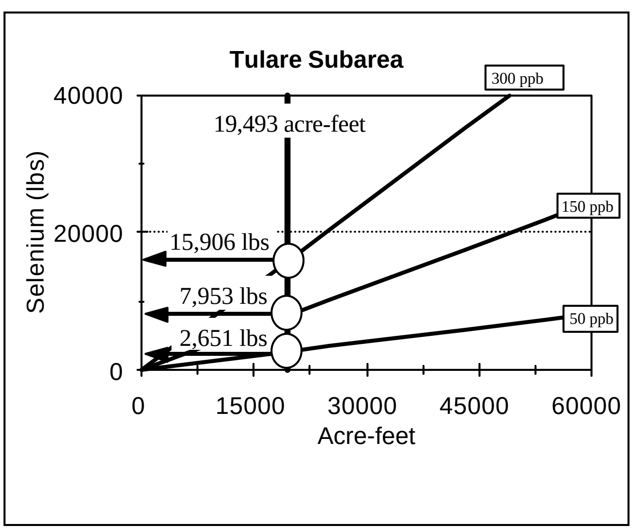


Figure B2d

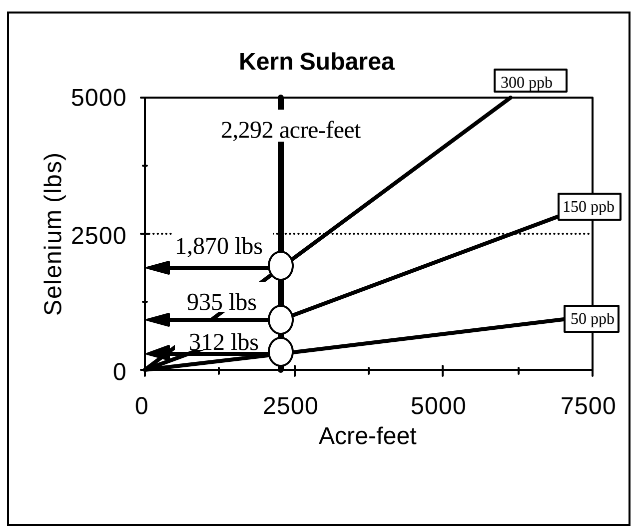


Figure B2e

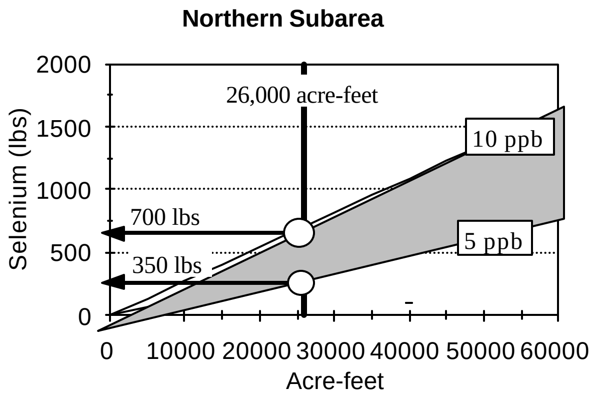


Figure B3a

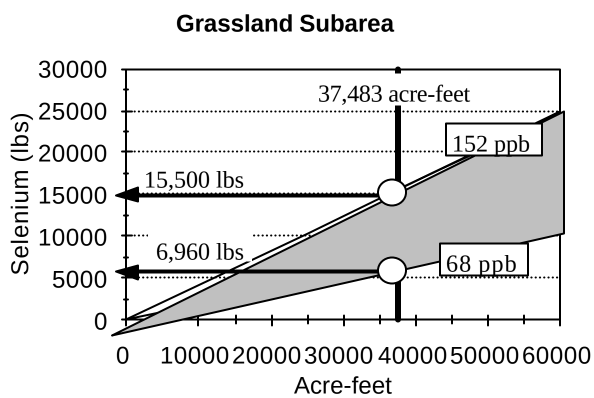


Figure B3b

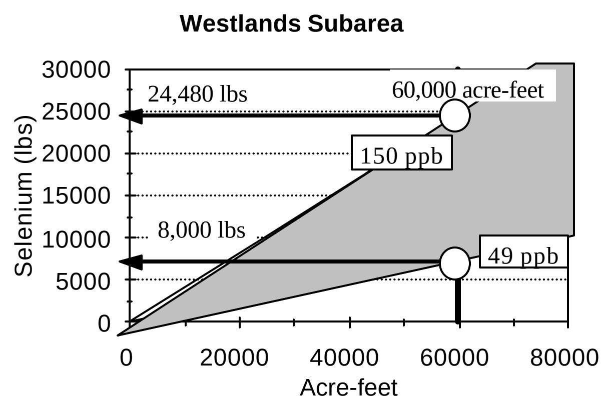


Figure B3c

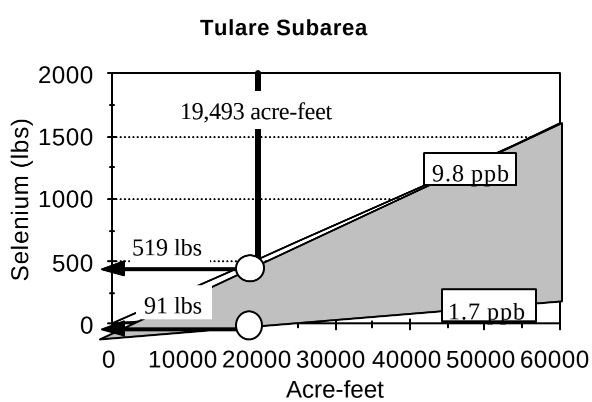
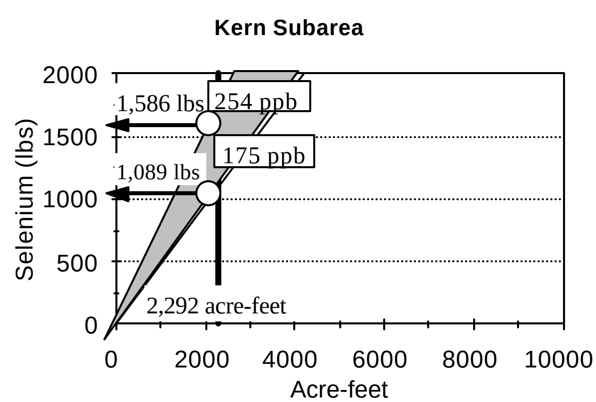


Figure B3d



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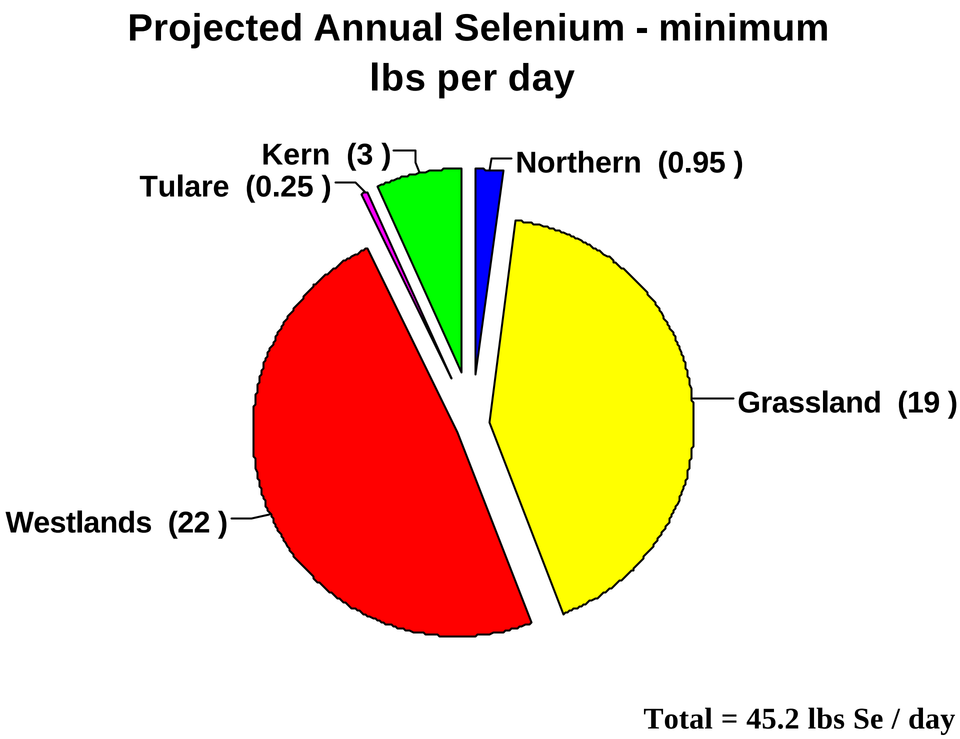

Figure B4a

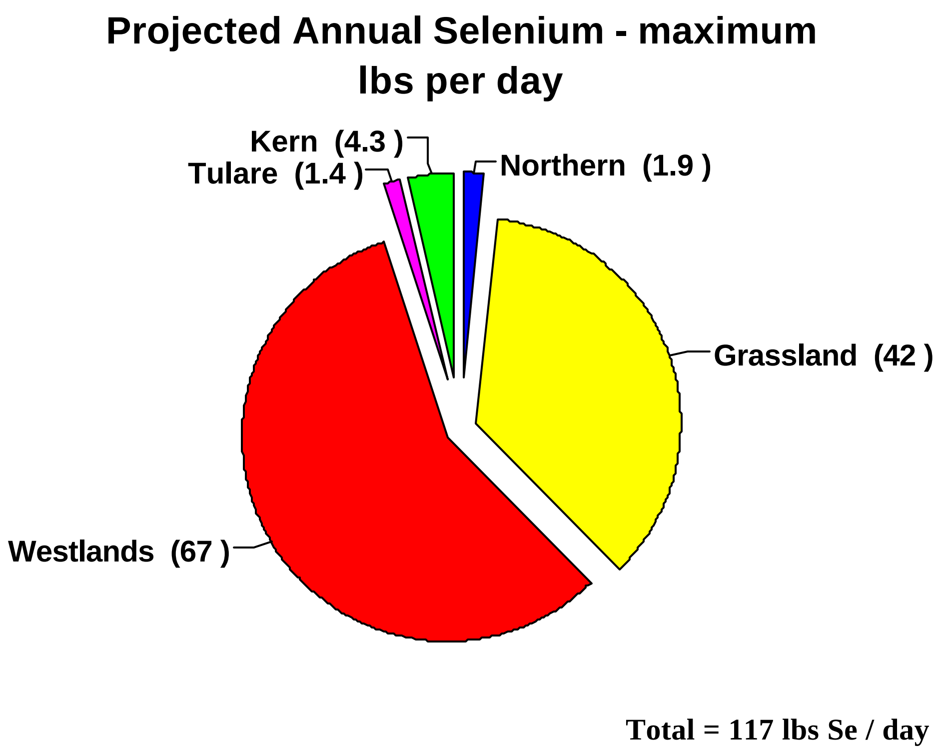

Figure B4b

Table B1 Westlands Water District Historical Selenium Loading

Use of San Luis Drain by Westlands Water District to discharge selenium to Kesterson Reservoir	WWD planned drainage acreage/ total acreage	Problem acreage with on-farm drains	Problem acre-feet	ppb Se	lbs Se/time interval	Calculated acre-feet/acre lbs Se/acre-foot
San Luis Drain discharge (measurement average 1983-1984) (CSWRCB, 1985; WWD, 1998)			38,450 (total discharge for 65 months; January 1981 to May 1986)	330-430		
Estimated Westlands Water District annual discharge to San Luis Drain from January, 1981-September, 1985 (Se concentrations from use of drain in 1983-1984) (CSWRCB, 1985)		5,000 (*42,000)	7,000	330-430	**6,283-8,187/year**	0.17-1.4 acre-feet/acre 0.898-1.17 lbs/AF
Projected Westlands Water District discharge to San Luis Drain by 1980 (based on 1965 management plans and Se concentrations from use of drain in 1983-1984) (WWD, 1996)	300,000/600,000 (approximately 566,500 irrigated acres)	76,000	38,000/year	330-430	**34,109-44,445 /year**	0.50 acre-feet/acre 0.898-1.17 lbs/AF
1986 Environmental Impact Statement (EIS) estimated San Luis Drain discharge (USBR, 1986): **Total (January, 1981- September, 1985)** **Annual (total averaged over 57 months)**					 **22,660** **4,776/year**	
1986 EIS estimated San Luis Drain discharge to Kesterson Reservoir (1981-1985) (USBR, 1986)					**17,400***** **(1 kesterson, kst)**	
1986 EIS estimated San Luis Drain bed sediment accumulation (95,271 cubic yards) (USBR, 1986)					**5,280**	

*****WWD contends that the drainage from 5,000 subsurface-drained acres actually represents drainage from 42,000 acres because of upslope contributions drained to this downslope area (CSWRCB, 1985); ** The 17,400-lb amount is referred to as one kesterson (kst). The use of this unit provides perspective on the quantity of Se that was a hazard to wildlife when released directly to the wetland at Kesterson Reservoir (Presser and Piper, 1998).

TABLE B2 Projections of annual selenium loading in the San Luis Drain using evidentiary evidence and selenium concentrations of 50, 150, and 300 ppb for WWD drainage and 62.5 ppb for Grassland Area drainage if drainage to the San Luis Drain is to resume by Westlands Water District and 2) if drainage to the San Luis Drain is to resume by Westlands Water District and drainage by the Grassland Area Farmers to the San Luis Drain is to continue.

Westlands Subarea or San Luis Unit	**Problem acre-feet***	**Calculated Acre-feet/ acre**	**Projected ppb Se**	**Projected lbs Se/year**	**Projected ppb Se**	**Projected lbs Se/year**	**Projected ppb Se**	**Projected lbs Se/year**
Barcellos Judgment*	not < 60,000 not > 100,000		**50**	**8,160-13,600**	**150**	**24,480-40,800**	**300**	**48,960-81,600**
DEIS Planning Alternatives*	24,000	0.23	**50**	**3,264**	**150**	**9,792**	**300**	**19,584**
Initial hook-up of 7,600 acreage of on-farm drains**	1,900- 2,300		**50**	**258-313**	**150**	**775-938**	**300**	**1,550- 1,877**
Drainage of 200,000 acres of problem acreage**	60,000	0.30	**50**	**8,160 (0.041lbs Se/acre or 0.136 lbs Se acre-foot)**	**150**	**24,480 (0.122 lbs Se/acre or 0.408 lbs Se acre-foot)**	**300**	**48,960 (0.245 lbs Se/acre or 0.816 lbs Se acre-foot)**
Additional drainage from Grassland Area Farmers**	30,000- 40,000		**62.5*****	**5,100- 6,800**	**62.5*****	**5,100- 6,800**	**62.5*****	**5,100-6,800**
Total for Westlands and Grassland (range)	90,000- 100,000			**13,518-15,273**		**30,355-32,218**		**55,610-57,637**

Evidence presented by Westlands Water District, 1*) D*raft Environmental Impact Statement, December 20, 1991, San Luis Drainage Program, Central Valley Project, California*, in partial answer to the Barcellos Judgment of December 30, 1986 (USBR, 1992) and 2**) *Statement Concerning Current Estimates of the Westlands Water District Drainage Problem*, submitted on the behalf of Westlands Water District, by William R. Johnston, April 4, 1996 (WWD, 1996); *** measured in water year (WY) 1997.

TABLE B3 Grassland Subarea discharge to the San Joaquin River for year 2000 and year 2040 using San Joaquin Valley Drainage Program drainage volumes and selenium concentrations for Zones A, B, and C (SJVDP, 1989; 1990a).

Grassland Subarea	*SJVDP 2000 drained acreage**	*SJVDP 2000 problem water acre-feet***	*SJVDP 2000 discharge to San Joaquin River(acre-feet)***	*Projected ppb Se***	*lbs Se/ acre-foot*	***Projected lbs Se/year***	*SJVDP 2040 discharge to San Joaquin River(acre-feet)***	*Projected ppb Se***	***Projected lbs Se/year***	*lbs Se/ acre-foot*
Zone A	72,000	54,000	10,700	150	0.408	**4,366**	21,000	75	**4,284**	0.204
Zone B	14,000	10,600	7,000	2	0.0054	**38**	17,600	2	**96**	0.0054
Zone C	30,000	22,000	22,000	2	0.0054	**120**	63,500	2	**345**	0.0054
Total	**116,000**	**86,600**	**39,700**			**4,524**	**102,100**		**4,725**	

* Preliminary Planning Alternatives, SJVDP, 1989, page 4-23 (assumption, drained acres will more than double by year 2000); ** SJVDP data from Table 29 and page 139.

Table B4 Annual acre-feet, selenium concentrations, and selenium loads from the Grassland Area Farmers Drainage Problem Area.

Water-year	acre-feet/year	ppb Se (total)	lbs Se/year	lbs Se/acre-foot
1986	67,006	52.3	9,524	0.142
1987	74,902	53.8	10,959	0.146
1988	65,327	56.8	10,097	0.154
1989	54,186	59.2	8,718	0.161
1990	41,662	65.2	7,393	0.177
1991	29,290	73.5	5,858	0.200
1992	24,533	76.2	5,083	0.207
1993	41,197	79.0	8,856	0.215
1994	38,670	80.5	8,468	0.219
1995	57,574	75.8	11,875	0.206
1996	52,978	70	10,034	0.189
1997*	37,483	62.5	7,097	0.186
1998*			9,118	
TOTAL			113,080 average 8,698 lbs/year	

DATA: CCVRWQCB, 1996b; c; 1998d; e; f; g; h; 2000,b; c; USBR et al., 1998, 1999.

* measured at the SLD discharge to Mud Slough after the initiation of the Grassland Bypass Channel Project

Table B5 Annual acre-feet, selenium concentrations, and selenium loads from Mud and Salt Sloughs.

Water-year	acre-feet/year	ppb Se (total)	lbs Se/year	Mud Slough concentration range	Salt Slough concentration range
1986	284,316	8.6	**6,643**	2.3-22	1.4-22
1987	233,843	12.0	**7,641**	1.7-26	5.2-26
1988	230,454	13.0	**8,132**	1.4-18	1.6-27
1989	211,393	14.1	**8,099**	0.7-5.0	2.7-33
1990	194,656	14.6	**7,719**	0.6-8.1	4.2-36
1991	102,162	14.0	**3,899**	0.7-38	0.9-30
1992	85,428	12.6	**2,919**	0.8-48	0.6-27
1993	167,955	15.0	**6,871**	1.0-5.0	0.5-42
1994	183,546	16.0	**7,980**	0.5-22	1.2-44
1995	263,769	14.9	**10,694**	0.7-4.2	0.8-38
1996	267,344	13	**9,697**	--	--
1997	288,253	10	**7,722**	5.0-80	0.5-3.4
1998			**Not available**		
Total			**88,016** **average 7,335 lbs/year**		

DATA: DATA: CCVRWQCB, 1996b; c; 1998d; e; f; g; h; 2000,b; c; USBR et al., 1998, 1999.

Table B6 Annual acre-feet, selenium concentrations, and selenium loads measured at the San Joaquin River near Patterson/Crows Landing.

Water-year (WY)	million acre-feet/year	ppb Se (total)	lbs Se/year	concentration range
1986	2.67	1.6	11,305	<1-4
1987	0.66	4.9	8,857	3.6-12
1988	0.55	6.2	9,330	0.8-12
1989	0.44	6.3	7,473	3.4-17
1990	0.40	5.6	6,125	1.6-13
1991	0.29	4.5	3,548	0.9-11
1992	0.30	3.7	3,064	0.7-11
1993	0.89	3.5	8,379	0.4-8.0
1994	0.56	4.8	7,270	<0.4-13
1995	3.50	1.6	14,291	0.6-12
1996	1.44	3	10,686	--
1997	4.18 (range 986 to 73,458 daily) (3.73 USGS from GBCP data)	1	8,667 (9,054 USGS from GBCP data)	0.1-10
1998	5.13 (range 956-47,916 daily) (GBCP data)		15,501 (GBCP data)	0.4 to 4.1
Total			114,496 average 8,807 lbs/year	

DATA: DATA: CCVRWQCB, 1996b; c; 1998d; e; f; g; h; 2000,b; c; USBR et al., 1998, 1999.

Table B7 Annual acre-feet, selenium concentrations, and selenium loads measured at the San Joaquin River near Vernalis.

Water-year	million acre-feet/year	ppb Se (total)	lbs Se/year	concentration range
1986	5.22	1.0	14,601	<0.1-1.4 (17?)
1987	1.81	1.8	8,502	0.6-3.2
1988	1.17	2.7	8,427	0.8-4.0
1989	1.06	3.0	8,741	1.7-6.8
1990	0.92	3.0	7,472	0.8-9.6
1991	0.66	2.0	3,611	0.5-4.8
1992	0.70	1.9	3,558	0.4-4.4
1993	1.70	1.9	8,905	<0.4-6.1
1994	1.22	2.3	7,760	0.4-6.3
1995	6.30	1.0	17,238	0.5-3.5
1996	3.95	1.1	11,431	
1997	6.77	0.6	11,190	
1998	8.5		15,810	
Total			127,246 average 9,788 lbs/year	

DATA: DATA: CCVRWQCB, 1996b; c; 1998d; e; f; g; h; 2000,b; c; USBR et al., 1998, 1999.

Table B8 San Luis Drain Re-use Project/Grassland Bypass Channel Project (1997-2001)

Use of San Luis Drain by Grassland Area Farmers (Grassland subarea Zone A) to discharge selenium to the San Joaquin River	**problem acreage**	**Measured problem acre-feet or discharge**	**Measured ppb Se**	**lbs Se/year**	**Calculated lbs/acre or lbs/acre-feet**	**Calculated acre-feet/acre**
CCVRWQCB prohibition limitation of Se discharge to the San Joaquin River or tributaries from tile or open drainage systems (effective October 1, 1996; CVRWQCB, 1996a; d)				**8,000**		
WY 1997-2001 San Luis Drain /Grassland Bypass Channel Project negotiated annual load target for discharge through the San Luis Drain to the San Joaquin River (USBR, 1995)	93,400			**5,661-6,660**	0.06-0.07/acre	
WY 1997 San Luis Drain /Grassland Bypass Channel Project measured load ** discharged through the drain to the San Joaquin River (USBR et al., 1998)**	97,400	37,483	62.5	**6,960**	0.073/acre 0.189/AF	0.38
January 26, 1997 estimated load from Coast Range runoff discharged through the drain (Grassland Area Farmers, 1997)				**137**		
WY 1998 San Luis Drain /Grassland Bypass Channel Project measured load discharged through the drain to the San Joaquin River (USBR et al., 1999)	97,400	45,858	66.9	**9,118**	0.094/acre 0.199/AF	0.47
February, 1998 estimated load from Coast Range runoff discharged through the drain (Grassland Area Farmers, 1997)				**487**		

Table B9 San Luis Drain Re-use Project/Grassland Bypass Channel Project WY 1997 Average Monthly Drainage Volumes and Selenium Concentrations, Annual Discharge, and Load Targets (USBR et al., 1998).

WY 1997	Measured acre-feet (AF)	Measured Se (ppb) (total)	Calculated Se (lbs)	Negotiated Se (lbs target)	Incentive fee ($)
Sept. 23-30,1996			[55 (est.)] *	see Sept, 1997	
October	1,274	60.8 (58.6)	202	348	0
November	1,566	58.3	252	348	0
December	1,943	51.5	285	389	0
January, 1997	3,696	59.5	599**	533	2,800
February	4,166	76.6	878**	866	700
March	4,867	84.2	1119	1066	700
April	4,446	105.5	1280	799	2,800
May	4,208	75.7	849	666	2,800
June	3,451	64.3	611	599	700
July	3,271	48.1	428	599	0
August	3,153	40.6	348	533	0
Sept, 1-30, 1997	1,442	25.3	109	350	0
Total (monthly)	**37,483**		**6,960**	**7,096 (monthly)**	**10,500**
Total (yearly)	**37,483**	**62.5 (average)**	**6,960**	**6,660 (yearly)**	**50,000**
WY 1997 storm discharge (lower watershed, Agatha Canal)			**137****		
Total (project plus storm discharge)			**7,097**		**$60,500**

* not counted in total; ** 89 lbs Se in January and 48 lbs Se in February discharged to wetland sloughs (Agatha Canal) during SLD overflow events due to storms in January and February, 1998.

Table B10 San Luis Drain Re-use Project/Grassland Bypass Channel Project WY 1998 Average Monthly Drainage Volumes and Selenium Concentrations, Annual Discharge, and Load Targets (USBR et al., 1999)

WY 1998	**Measured acre-feet (AF)**	**Measured Se (ppb) (total)**	**Calculated Se (lbs)**	**Negotiated Se (lbs target)**	**Incentive fees ($)**
October, 1997	1,753	51.9	248	348	0
November	1,555	48.9	207	348	0
December	1,403	48.7	178	389	0
January, 1998	1,419	85.0	335	533	0
February	6,980	52.5	965*	866	4,200**
March	7,094	83.3	1600	1066	4,200**
April	5,517	105.4	1554 (1560)	799	4,200**
May	4,881	104.5	1371	666	4,200**
June	3,629	82.1	807	599	4,200**
July	4,564	49.7	615	599	1200
August	3,876	47.5	500	533	0
September	3,187	43.1	388	350	2,200
Total (monthly)	**45,858**			**7,096 (monthly)**	
Total (yearly)	**45,858**	**66.9 (average)**	**8,768**	**6,660 (yearly)**	**150,000****
WY 1998 storm discharge (lower watershed, Agatha Canal))			**350***		
Total (project plus storm discharge)			**9,118**		**174,400 (3,400 paid)**

*350 lbs Se discharged to wetland sloughs (Agatha Canal) during SLD overflow events due to storms in February, 1998; fees waived because of above average rainfall for WY 1998.

Table B11 Acreage used for planning purposes in 1985-1990 by the SJVDP (SJVDP, 1989, Table 1-1)

Subarea	*SJVDP Acreage*	*SJVDP irrigable* acreage*	*SJVDP irrigated* acreage*	*SJVDP drained acreage*
Northern	236,000	165,000	157,000	26,000
Grassland*	707,000	345,000	311,000**	51,000
Westlands	770,000	640,000	576,000	5,000
Tulare	883,000	562,000	506,000**	42,000
Kern	1,210,000	762,000	686,000	11,000
Total	3,806,000	2,474,000	2,235,000	135,000

* A factor of 90 to 95% was used to calculate irrigated acres from irrigable acres (SJVDP, 1990a, Table 11; ** SJVDP, 1990a, Table 11, Grassland subarea 329,000 acres; Tulare subarea 551,000 acres.

Table B12 The SJVDP 1990 and year 2000 irrigated acreage, abandoned acreage, problem acreage and cost for problem water reduction based on implementation of the recommended SJVDP Management Plan (1990a). The "***without future***" (i.e., no implementation of a management plan) includes abandonment of lands due to salinization.

Subarea	*SJVDP 1990 irrigated acreage***	*SJVDP 2000 irrigated acreage*** ***without future***	*SJVDP 2000 abandoned acreage*** ***without future***	*SJVDP 2000 problem acreage**** ***without future***	*SJVDP problem water generation acre-feet/acre *****	*SJVDP 2000 problem acre-feet ******	*SJVDP 2040 problem acre-feet ******	*SJVDP annualized cost/acre for problem water reduction *******	*SJVDP annualized cost for management plan implementation *******
Northern	157,000	152,000	0	34,000	0.70-0.75	26,000	38,000	---	
Grassland*	329,000	325,000	0	116,000	0,70-0.75	86,000	155,000	$107	$12,412,000
Westlands	576,000	551,000	28,000	108,000	0.60	81,000	153,000	$136	$14,688,000
Tulare	551,000	517,000	38,000	125,000	0.70-0.75	75,000	209,000	$104	$13,000,000
Kern	686,000	665,000	18,000	61,000	0.71	46,000	111,000	$137	$ 8,357,000
Total	2,299,000	2,210,000	84,000	444,000		314,000	666,000		$48,457,000

* Grassland subarea total acreage is 707,000 with 329,000 irrigated acres (90% of irrigable lands) and the Grassland Area/Drainage Problem Area within the subarea is approximately 100,000 acres; ** SJVDP Table 11; *** SJVDP Table 9; **** SJVDP page 76;***** SJVDP Table 10; ****** 50 year planning period and based on year 2000 problem acreage SJVDP pages 5, 143, 148, 153, and 156 (approximately $42, 000,000, page 5); cost/acre includes the cost of fish and wildlife components.

Table B13 The SJVDP 1990, 2000, and 2040 volumes of drainage with no drainage improvement (0.75 acre-feet/acre/year) or minimal improvement (0.55 acre-feet/acre/year) (SJVDP, 1990a). The conditions without implementation of SJVDP management plan is designated by the SJVDP as the ***"without future"*** alternative and includes abandonment of lands due to salinization. An additional calculation is made for Westlands based on "upslope" contributions to the tile drained acreage from non-tile drained acreage (CSWRCB, 1985).

Subarea	*SJVDP 1990 tile-drained acres **	*factor AF/ acre/ year*	***SJVDP 1990 drainage volumes (acre-feet)****	*SJVDP 2000 tile-drained acres* ***without future****	*factor AF/ acre/ year*	***SJVDP 2000 drainage volumes (acre-feet) without future****	*SJVDP 2040 tile-drained acres* ***without future****	*factor AF/ acre/ year*	***SJVDP 2040 drainage volumes (acre-feet without future *****
Northern	24,000	0.75	**18,000**	34,000	--***	**26,000**	51,000	0.75	**38,000********
Grassland	50,000	0.75	**38,000**	85,000	--	**54,000**	152,000	0.55	**84,000********
Westlands	5,000	0.75	**4,000**	50,000	--	**28,000**	49,000	0.55	**27,000**
Westlands	42,000*****	0.75	**31,500*********	--			--		
Tulare	43,000	0.60	**32,000**	86,000	--	**47,000**	94,000	0.55	**52,000**
Kern	11,000	0.75	**8,000**	14,000	--	**8,000**	40,000	0.55	**22,000**
Total	133,000		**100,000**	269,000	--	**163,000**	386,000		**223,000**

* SJVDP Table 11; ** SJVDP Table13; *** no factor given by SJVDP, Table 13; **** In SJVDP Table 13 the values are 37,000 and 105,000 acre-feet.
***** not included in total

Table B14 Calculated volume of drainage using a drainage improvement factor of 0.40 acre-feet/acre/year (SJVDP, 1990a). The alternative with Implementation of the SJVDP management plan is designated by the SJVDP as the ***"with future"*** alternative. An additional calculation is made for Westlands based on "upslope" contributions to the tile drained acreage from non-tile drained acreage (CSWRCB, 1985).

Subarea	*SJVDP 1990 tile-drained acres***	*factor AF/ acre/ year****	***Calculated 1990 drainage volumes (acre-feet) with future***	*SJVDP2000 tile-drained acres* ***with future*******	*factor AF/ acre/ year ****	***Calculated 2000 drainage volumes (acre-feet) with future***	*SJVDP2040 tile-drained acres* ***with future*******	*factor AF/ acre/ year ****	***Calculated 2040 drainage volumes (acre-feet) with future***
Northern*	24,000	0.40	**9,600**	34,000	0.40	**13,600**	44,000	0.40	**17,600**
Grassland	50,000	0.40	**20,000**	108,000	0.40	**43,200**	192,000	0.40	**76,800**
Westlands	5,000	0.40	**2,000**	69,000	0.40	**27,600**	140,000	0.40	**56,000**
Westlands	42,000****	0.40	**16,800******						
Tulare	43,000	0.40	**17,200**	96,000	0.40	**38,400**	277,000	0.40	**110,800**
Kern	11,000	0.40	**4,400**	53,000	0.40	**21,200**	106,000	0.40	**42,400**
Total	133,000		**53,200**	360,000		**144,000**	759,000		**303,600**

* No management plan recommended for Northern subarea; **SJVDP Table 27; *** factor applied from SJVDP Table 26; **** not included in total.

Table B15a Projections of annual selenium loading per subarea for year 2000 using San Joaquin Valley Drainage Program ***problem water*** volumes (***"without future"*** alternative, 0.60 to 0.75 acre-feet/acre/year; SJVDP, 1990a) and a 50-ppb Se concentration in drainage discharge.

Subarea	*SJVDP 2000 problem acreage**	*SJVDP problem water generation acre-feet/acre/ year***	*SJVDP 2000 problem acre-feet ****	***Projected ppb Se***	***Projected lbs Se/year***	*Calculated lbs Se/acre*	*Calculated lbs Se/acre-foot*
Northern	34,000	0.70-0.75	26,000	**50**	**3,536**	0.1	0.136
Grassland	116,000	0,70-0.75	86,000	**50**	**11,696**	0.1	0.136
Westlands	108,000	0.70- 0.75	81,000	**50**	**11,016**	0.1	0.136
Tulare	125,000	0.60	75,000	**50**	**10,200**	0.08	0.136
Kern	61,000	0.70-0.75	46,000	**50**	**6,256**	0.1	0.136
Total	444,000	0.71	314,000	**50**	**42,704**	0.096	0.136

* SJVDP Table 9; ** SJVDP page 76 and *** SJVDP Table 10

Table B15b Projections of annual selenium loading per subarea for year 2000 using San Joaquin Valley Drainage Program ***problem water*** volumes (***"without future"*** alternative, 0.60 to 0.75 acre-feet/acre/year; SJVDP, 1990a) and a 150-ppb Se concentration in drainage discharge.

Subarea	*SJVDP 2000 problem acreage**	*SJVDP problem water generation acre-feet/acre/ year***	*SJVDP 2000 problem acre-feet ****	***Projected ppb Se***	***Projected lbs Se/year***	*Calculated lbs Se/acre*	*Calculated lbs Se/acre-foot*
Northern	34,000	0.70-0.75	26,000	**150**	**10,608**	0.31	0.408
Grassland	116,000	0,70-0.75	86,000	**150**	**35,088**	0.31	0.408
Westlands	108,000	0.70- 0.75	81,000	**150**	**33,048**	0.31	0.408
Tulare	125,000	0.60	75,000	**150**	**30,600**	0.24	0.408
Kern	61,000	0.70-0.75	46,000	**150**	**18,768**	0.31	0.408
Total	444,000	0.71	314,000	**150**	**128,112**	0.29	0.408

* SJVDP Table 9; ** SJVDP page 76 and *** SJVDP Table 10

Table B15c Projections of annual selenium loading per subarea for year 2000 using San Joaquin Valley Drainage Program ***problem water*** volumes (***"without future"*** alternative, 0.60 to 0.75 acre-feet/acre/year; SJVDP, 1990a) and a 300-ppb Se concentration in drainage discharge.

Subarea	*SJVDP 2000 problem acreage**	*SJVDP problem water generation acre-feet/acre/ year***	*SJVDP 2000 problem acre-feet ****	***Projected ppb Se***	***Projected lbs Se/year***	*Calculated lbs Se/acre*	*Calculated lbs Se/acre-foot*
Northern	34,000	0.70-0.75	26,000	**300**	**21,216**	0.31	0.816
Grassland	116,000	0,70-0.75	86,000	**300**	**70,176**	0.31	0.816
Westlands	108,000	0.70- 0.75	81,000	**300**	**66,096**	0.31	0.816
Tulare	125,000	0.60	75,000	**300**	**61,200**	0.24	0.816
Kern	61,000	0.70-0.75	46,000	**300**	**37,536**	0.31	0.816
Total	444,000	0.71	314,000	**300**	**256,224**	0.29	0.816

* SJVDP Table 9; ** SJVDP page 76 and *** SJVDP Table 10

Table B16a Projections of annual selenium loading per subarea for year 2000 using San Joaquin Valley Drainage Program ***subsurface drainage volumes*** (***"without future"*** alternative, 0.60 to 0.75 acre-feet/acre/year; SJVDP, 1990a) and Se concentrations of 50, 150, and 300 ppb.

Subarea	*SJVDP 2000 drained acreage* ***without future*** *	*SJVDP 2000 subsurface drainage volume (acre-feet)* ***without future*****	***Projected ppb Se***	***Projected lbs Se/year***	***Projected ppb Se***	***Projected lbs Se/year***	***Projected ppb Se***	***Projected lbs Se/year***
Northern	34,000	26,000	**50**	**3,536**	**150**	**10,608**	**300**	**21,216**
Grassland	85,000	54,000	**50**	**7,344**	**150**	**22,032**	**300**	**44,064**
Westlands	50,000	28,000	**50**	**3,808**	**150**	**11,424**	**300**	**22,848**
Tulare	86,000	47,000	**50**	**6,392**	**150**	**19,176**	**300**	**38,352**
Kern	14,000	8,000	**50**	**1,088**	**150**	**3,264**	**300**	**6,528**
Total	269,000	163,000	**50**	**22,168**	**150**	**66,504**	**300**	**133,008**

* SJVDP Table 11; ** SJVDP Table 13.

Table B16b Projections of annual selenium loading per subarea for year 2000 using San Joaquin Valley Drainage Program ***subsurface drainage volumes*** (***"with future"*** alternative, 0.40 acre-feet/acre/year; SJVDP, 1990a) and Se concentrations of 50, 150, and 300 ppb.

Subarea	*SJVDP 2000 drained acreage* ***with future*** *	*SJVDP 2000 subsurface drainage volume (acre-feet)* ***with future*****	***Projected ppb Se***	***Projected lbs Se/year***	***Projected ppb Se***	***Projected lbs Se/year***	***Projected ppb Se***	***Projected lbs Se/year***
Northern	34,000	13,600	**50**	**1,850**	**150**	**5,549**	**300**	**11,098**
Grassland	108,000	43,200	**50**	**5,875**	**150**	**17,625**	**300**	**35,251**
Westlands	69,000	27,600	**50**	**3,754**	**150**	**11,261**	**300**	**22,522**
Tulare	96,000	38,400	**50**	**5,222**	**150**	**15,667**	**300**	**31,334**
Kern	53,000	21,200	**50**	**2,883**	**150**	**8,650**	**300**	**17,299**
Total	360,000	144,000	**50**	**19,584**	**150**	**58,752**	**300**	**117,504**

* SJVDP Table 11; ** SJVDP Table 13.

Table B16c Projections of annual selenium loading per subarea for year 2000 using San Joaquin Valley Drainage Program ***subsurface drainage volumes***, our ***"with targeted future"*** alternative (0.20 acre-feet/acre/year; SJVDP, 1990a), and Se concentrations of 50, 150, and 300 ppb.

Subarea	*SJVDP 2000 drained acreage* ***with future*** *	*SJVDP 2000 subsurface drainage volume (acre-feet)* ***with targeted future*****	***Projected ppb Se***	***Projected lbs Se/year***	***Projected ppb Se***	***Projected lbs Se/year***	***Projected ppb Se***	***Projected lbs Se/year***
Northern	34,000	6,800	**50**	**925**	**150**	**2,774**	**300**	**5,549**
Grassland	108,000	21,600	**50**	**2,938**	**150**	**8,813**	**300**	**17,626**
Westlands	69,000	13,800	**50**	**1,877**	**150**	**5,630**	**300**	**11,261**
Tulare	96,000	19,200	**50**	**2,611**	**150**	**7,834**	**300**	**15,667**
Kern	53,000	10,600	**50**	**1,442**	**150**	**4,325**	**300**	**8,650**
Total	360,000	72,000	**50**	**9,793**	**150**	**29,376**	**300**	**58,753**

* SJVDP Table 11; ** applied factor of 0.20 acre-feet/acre

Table B17 Our projections of annual selenium loading for subareas for year 2000 using Se concentrations of 50 ppb, 150 ppb, and 300 ppb and SJVDP volumes of ***problem water " without future"*** *alternative*, of **drainage volumes** in the ***"without future"*** alternative and in the ***"with future"*** alternative (SJVDP, 1990a). In the "***with targeted future***" alternative, we applied a factor of 0.2 acre-feet/acre/year.

Subarea	*1990 subsurface drainage acre-feet/ year*	*ppb Se*	***lbs Se/ year***	*projected 2000* ***problem water*** *acre-feet/ year**	*ppb Se*	***lbs Se/ year***	*projected 2000 drainage acre-feet/year* ***without future********	*ppb Se*	***lbs Se/ year***	*projected 2000 drainage acre-feet/year* ***with future*********	*ppb Se*	***lbs Se/ year***	*projected 2000 drainage acre-feet/year* ***with targeted future*********	*ppb Se*	***lbs Se/ year***
Northern*	18,000	50	**2,448**	26,000	50	**3,536**	26,000	50	**3,536**	13,600	50	**1,850**	6,800	50	**925**
Grassland	38,000	50	**5,168**	86,000	50	**11,696**	54,000	50	**7,344**	43,200	50	**5,875**	21,600	50	**2,938**
Westlands	4,000	50	**544**	81,000	50	**11,016**	28,000	50	**3,808**	27,600	50	**3,754**	13,800	50	**1,877**
Tulare	32,000	50	**4,352**	75,000	50	**10,200**	47,000	50	**6,392**	38,400	50	**5,222**	19,200	50	**2,611**
Kern	8,000	50	**1,088**	46,000	50	**6,256**	8,000	50	**1,088**	21,200	50	**2,883**	10,600	50	**1,442**
Total	100,000		**13,600**	314,000		**42,704**	163,000		**22,168**	144,000		**19,584**	72,000		**9,793**

Subarea	*1990 subsurface drainage acre-feet/ year*	*ppb Se*	***lbs Se/ year***	*projected 2000* ***problem water*** *acre-feet/ year**	*ppb Se*	***lbs Se/ year***	*projected 2000 drainage acre-feet/year* ***without future********	*ppb Se*	***lbs Se/ year***	*projected 2000 drainage acre-feet/year* ***with future*********	*ppb Se*	***lbs Se/ year***	*projected 2000 drainage acre-feet/year* ***with targeted future*********	*ppb Se*	***lbs Se/ year***
Northern*	18,000	150	**7,344**	26,000	150	**10,608**	26,000	150	**10,608**	13,600	150	**5,549**	6,800	150	**2,774**
Grassland	38,000	150	**15,504**	86,000	150	**35,088**	54,000	150	**22,032**	43,200	150	**17,625**	21,600	150	**8,813**
Westlands	4,000	150	**1,632**	81,000	150	**33,048**	28,000	150	**11,424**	27,600	150	**11,260**	13,800	150	**5,630**
Tulare	32,000	150	**13,056**	75,000	150	**30,600**	47,000	150	**19,176**	38,400	150	**15,667**	19,200	150	**7,834**
Kern	8,000	150	**3,264**	46,000	150	**18,768**	8,000	150	**3,264**	21,200	150	**8,650**	10,600	150	**4,325**
Total	100,000		**40,800**	314,000		**128,112**	163,000		**66,504**	144,000		**58,751**	72,000		**29,376**

Subarea	*1990 subsurface drainage acre-feet/ year*	*ppb Se*	***lbs Se/ year***	*projected 2000 problem water acre-feet/ year**	*ppb Se*	***lbs Se/ year***	*projected 2000 drainage acre-feet/year* ***without future********	*ppb Se*	***lbs Se/ year***	*projected 2000 drainage acre-feet/year* ***with future*********	*ppb Se*	***lbs Se/ year***	*projected 2000 drainage acre-feet/year* ***with targeted future*********	*ppb Se*	***lbs Se/ year***
Northern*	18,000	300	**14,688**	26,000	300	**21,216**	26,000	300	**21,216**	13,600	300	**11,098**	6,800	300	**5,549**
Grassland	38,000	300	**31,008**	86,000	300	**70.176**	54,000	300	**44,064**	43,200	300	**35,251**	21,600	300	**17,626**
Westlands	4,000	300	**3,264**	81,000	300	**66,096**	28,000	300	**22,848**	27,600	300	**22,522**	13,800	300	**11,261**
Tulare	32,000	300	**26,112**	75,000	300	**61,200**	47,000	300	**38,352**	38,400	300	**31,334**	19,200	300	**15,667**
Kern	8,000	300	**6.528**	46,000	300	**37,536**	8,000	300	**6,528**	21,200	300	**17,299**	10,600	300	**8,650**
Total	100,000		**81,600**	314,000		**256,224**	163,000		**133,008**	144,000		**117,504**	72,000		**58,753**

*SJVDP Table 10; ** SJVDP Table 13; *** see calculation this report Table – (SJVDP Table 27 acreage with factor applied from SJVDP Table 26); **** this report Table 15.

Table B18 Summary of our projections of annual selenium loads for SJVDP subareas for year 2000. Scenarios 1, 2, 3: assigned selenium concentrations of 50, 150, 300 ppb Se and SJVDP estimates of drainage volume (SJVDP, 1990a).

Subarea **acre-feet/year**	**Assigned concentration** **50 ppb (0.136 lbs Se/acre-foot)** **(lbs Se/year)**	**Assigned concentration** **150 ppb (0.408 lbs Se/acre-foot)** **(lbs Se/year)**	**Assigned concentration** **300 ppb (0.817 lbs Se/acre-foot)** **(lbs Se/year)**
Northern			
6,800	925	2,774	5,549
13,600	1,850	5,549	11,098
26,000	3,536	10,608	21,216
Grassland			
21,600	2,938	8,813	17,626
43,200	5,875	17,625	35,251
54,000	7,344	22,032	44,064
86,000	11,696	35,088	70,176
Westlands			
13,800	1,877	5,630	11,261
27,600	3,754	11,260	22,522
28,000	3,808	11,424	22,848
81,000	11,016	33,048	66,096
Tulare			
19,200	2,611	7,834	15,667
8,400	5,222	15,667	31,334
47,000	6,392	19,176	38,382
75,000	10,200	30,600	61,200
Kern			
8,000	1,088	3,264	6,528
10,600	1,442	4,325	8,650
21,200	2,883	8,650	17,299
46,000	6,256	18,768	37,536
Total drainage/year, all subareas **Range 69,400 to 314,000 acre-feet**			
Total lbs Se/year			
Minimum lbs, all subareas	**9,284**	**27,847**	**55,652**
Minimum lbs without Northern	**8,367**	**25,073**	**50,103**
Maximum lbs, all subareas	**42,704**	**128,112**	**256,224**
Maximum lbs, without Northern	**39,168**	**117,504**	**235,008**

Table B19 Tulare subarea 1988-1989 drainage discharges and selenium concentrations.

Discharge to 21 privately owned evaporation basins 1988 and 1989*	Drainage acre-feet/year	ppb Se (measurement or range)	lbs Se/year
1988 TOTAL/YEAR			
TLDD (Total)	14,294		
north		2.6	
hacienda		--	
south		30	
Westlake		1-1.1	
Meyer		1	
Stone		1.6-4.3	
Britz		--	
Others		9.6-757	
1989 TOTAL/YEAR			
TLDD (Total)	13,705		
north		2.0	
hacienda		---	
south		21	
Westlake		0.4-6.5	
Meyer		0.8	
Stone		2.3-7.4	
Britz		---	
Others		1.0-62	

*Discharge data from CCVRWQCB, pers. com., Anthony Toto, 1998; Se concentration data from *Water Quality in Evaporation Basins Used for the Disposal of Agricultural Subsurface Drainage Water in the San Joaquin Valley, California*, 1988 and 1989 (CCVRWQCB, 1990a).

Table B20 Tulare subarea 1993-1997 drainage discharges and selenium concentrations.

Discharge to privately owned evaporation basins 1993-1997*	Drainage acre-feet/year	ppb Se (measurement or range)	lbs Se/year
1993 TOTAL/YEAR	17,899-18,955		**91-97**
TLDD (Total)**	12,497 (net)***; 13,553 (gross)	1.9 avg	**65-71**
north		1.4	
hacienda		2.1	
south		2.0	
Westlake	4,309	1.3	**15**
Meyer	--	--	**--**
Stone	1,093	3.6	**10.7**
Britz	--	124	**--**
1994 TOTAL/YEAR	19,468		
TLDD (Total)**	14,601		
north	1,432	1.8	**7.0**
hacienda	4,226	----	
south	8,943	12.6	**306**
Westlake	3,478	1.2	**11.6**
Meyer	--	--	**--**
Stone	1,213	3.7	**12.2**
Britz	186	15-50	**7.6-25.3**
1995 TOTAL/YEAR	20,403		**494-519**
TLDD (Total)**	14,751		**461**
north	1,373	2.5	**9.3**
hacienda	4,754	13.2	**171**
south	8,624	12.0	**281**
Westlake	3,478	2.25 avg	**21**
Meyer	327	0.76	**0.7**
Stone	1,665	2.4	**10.9**
Britz	182	15-50	**7.4-25**
1996 TOTAL/YEAR	19,160		
TLDD (Total)**	13,676		
north	918	2.5	**6.2**
hacienda	4,515	---	
south	8,243	8.3	**186**
Westlake	5,152	----	**--**
Meyer	332	0.99	**0.894**
Stone	--	--	**--**
Britz	--	--	**--**
1997 TOTAL/ Water year	20,005		**252-442**
TLDD (Total)**	15,605		**240-430**
north	1,199	2.1/1.8****	**6.8-5.9**
hacienda	5,238	---/5.9	**84**
south	9,168	13.6/6.0	**339-150**
Westlake	4,400	2.27 avg	**12**
Meyer	--	--	**--**
Stone	--	--	**--**
Britz	--	--	**--**

** 1993-1997data from CCVRWQCB, pers. com. Anthony Toto, 1998; ** Tulare Lake Drainage District*** net=gross minus interceptor seepage; **** two samplings for WY 1997, June and September, 1997.*

Table B21 Kern subarea 1988-1997 drainage discharges and selenium concentrations.

Kern Subarea **Discharge to privately owned evaporation basins 1988, 1989, 1993-1997***	**Drainage** **acre-feet/year**	**ppb Se**	**lbs Se/year**
1988 TOTAL/YEAR			
Lost Hills Water District	2,452	142	**947**
Rainbow Ranch		---	
Lost Hills Ranch		2.4	
1989 TOTAL/YEAR			
Lost Hills Water District	3,831	83-671	**865-6,992**
Rainbow Ranch		212	
Loast Hills Ranch		2.1	
1993 TOTAL/YEAR	2,467		**1,426**
Lost Hills Water District	1,854	220	**1109**
Rainbow Ranch	613	190	**317**
1994 TOTAL/YEAR	2,318		**1,586**
Lost Hills Water District	1,739	208	**948**
Rainbow Ranch	579	405	**638**
1995 TOTAL/YEAR	2,237		**1,410**
Lost Hills Water District	1,549	240	**1011**
Rainbow Ranch	688	213	**399**
1996 TOTAL/YEAR	2,365		**1,407**
Lost Hills Water District	1,501	238	**972**
Rainbow Ranch	864	185	**435**
1997 TOTAL/YEAR	2,072		**1,089**
Lost Hills Water District	1,620	195	**859**
Rainbow Ranch	452	187	**230**

* Data from C*CVRWQCB, pers. com. Anthony Toto*, 1998, except for selenium concentrations for 1988 and 1989 which are from *WaterQuality in Evaporation Basins Used for the Disposal of Agricultural Subsurface Drainage Water in the San Joaquin Valley, California*, 1988 and 1989 (CCVRWQCB, 1990).

Table B22 Planned capacity of the San Luis Drain or Valley-Wide Drain. Loading scenarios use assigned selenium concentrations of 50 ppb, 150, ppb, and 300 ppb.

San Luis Drain Design Capacity	@ 50 ppb lbs Se/year	@ 150 ppb lbs Se/year	@ 300 ppb lbs Se/year
300 cfs or 216,810 acre-feet/year (USBR, 1955) planned capacity Bakersfield to Mendota section	29,486	88,458	176,917
450 cfs or 325,215 acre-feet/year (USBR, 1955) planned capacity Kesterson Reservoir to Bay/Delta section	44,229	132,688	265,375
144,200 acre-feet/year (USBR, 1950's, initially needed)	19,611	58,834	117,667
after 50 years 154,100 acre-feet/year, maximum (range 3,100 to 154,100 acre-feet/year (USBR, 1978)	20,958	62,873	125,746
after 25 years 201,025 acre-feet/year (range 84,525 to 279,270 acre-feet/year (USBR, 1983)	27,339	82,018	164,036
Barcellos Judgment 60,000 to 100,000 acre-feet/year (USBR,1992)	8,160-13,600	24,480-40,800	48,960-81,600
Westland Water District 60,000 acre-feet/year	8,160	24,480	48,960
375,000 acre-feet/year (400,000-500,000 acre-feet/year needed capacity) (San Francisco Ocean Out-fall, Montgomery Watson, 1993)	51,000	153,000	306,000

Table B23a San Joaquin Valley Drainage Program generalized projected annual selenium discharge from the western San Joaquin Valley to a proposed San Luis Drain extension to the Bay/Delta. A selenium concentration of 50 ppb Se was hypothesized to be attainable with treatment; a concentration of 150 ppb Se is assigned to subsurface drainage.

San Joaquin Valley acre-feet (all subareas)	**lbs Se/ year**	kestersons*/year (ksts/year)	lbs Se/day	Se Concentration ppb	Se Concentration lbs Se/acre-foot
314,000 (problem water at 50 ppb Se)	**42,704**	2.45	117	50	0.136
144,000-163,000 (subsurface drainage at 150 ppb Se)	**58,752-66,504**	3.4-3.8	161-182	150	0.408

Table 23b Projected low-range annual selenium discharges from the western San Joaquin Valley to a San Luis Drain extension to the San Francisco Bay/Delta

San Joaquin Valley Subarea	**lbs Se/ year**	kestersons*/year (ksts/year)	lbs Se/day	Se Concentration ppb	Se Concentration lbs Se/acre-foot
Northern	**350**	0.02	0.95	5	0.0135
Grassland	**6,960**	0.40	19	68	0.186
Westlands	**8,000**	0.46	22	49	0.133
Tulare	**91**	0.005	0.25	1.7	0.0047
Kern	**1,089**	0.062	3.0	175	0.475
TOTAL	**16,490**	**0.95**	**45.2**		

Table 23c Projected high-range annual selenium discharges from the western San Joaquin Valley to a San Luis Drain extension to the San Francisco Bay/Delta

San Joaquin Valley Subarea	**lbs Se/ year**	kestersons*/year (ksts/year)	lbs Se/day	Se Concentration ppb	Se Concentration lbs Se/acre-foot
Northern	**700**	0.04	1.9	10	0.027
Grassland	**15,500**	0.89	42	152	0.414
Westlands	**24,480**	1.4	67	150	0.408
Tulare	**519**	0.03	1.4	9.8	0.0266
Kern	**1,586**	0.09	4.3	254	0.692
TOTAL	**42,785**	**2.46**	**117**		

*one kesterson = 17,400 lbs Se

APPENDIX C

Agricultural Drainage Discharge to the San Joaquin River

APPENDIX C

Agricultural Drainage Discharge to the San Joaquin River

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C2. Modeled (TMDL, Total Maximum Daily Load model) Annual Selenium Load Allowance to the San Joaquin River from the Grassland Area.

C3. Modeled (TMML model, Total Maximum Monthly Load model and DRT model, Dynamic Real-Time model) Annual Selenium Load Allowance to the San Joaquin River from the Grassland Area.

APPENDIX C

Agricultural Drainage Discharge to the San Joaquin River

Models of Discharge to the San Joaquin River

In 1991 and 1992, the state acknowledged continuing elevated levels of Se in the SJR and parts of the Bay-Delta by declaring the lower 130-mile reach of the SJR a *water-quality limited segment* (e.g., CCVRWQCB, 1994a; 1998b) and the Se levels in the bay *of concern* (CSFBRWQCB, 1992a). Discharge of Se to the SJR has continued based on an agreement to implement a regulatory control program for Se discharges started the year that Kesterson Reservoir was buried (CSWRCB, 1985 and 1987). Figure C1 shows the number of months per year that the USEPA 5 µg Se/L Se standard was violated at the state compliance point for the SJR as a receiving water (i.e., SJR at Crows Landing) from 1986 to 1997. The number of violations is based on a mean monthly average of a varying number of collected grab samples (CCVRWQCB, 1998d,e,f,g,h,). In 1999, the state placed the SJR and the entire San Francisco Bay on the high priority list in the Consolidated Toxic Hot Spot Cleanup Plan (CSWRCB, 1999c). Besides the USEPA promulgated Se standard for the protection of aquatic life, an annual prohibition limitation of 8,000 lbs Se exists as part of the state San Joaquin and Sacramento River Basin Plan since 1996 and *waste discharge requirement* for Se discharge to the SJR since 1998. Violations of this prohibition recently have occurred at the SJR at Crows Landing from WY 1995 through WY 1998 when 14,291 lbs Se, 10,868 lbs Se, 8,667 lbs Se, and 13,445 lbs Se were discharged annually during those years.

The Clean Water Act as amended in 1987 [section 303 (d)(l)(c)] requires that water-quality standards be converted into Total Maximum Daily Loads (TMDLs) in the water-quality impaired water bodies like the lower reach of the SJR. The TMDL approach allows a state to implement water-quality control measures where beneficial uses are known to be impaired, but the resource is not being regulated because of lack of adequate data. In the case of Se, both the existing record and developed models for the SJR have important limitations (Presser and Piper, 1998). The existing record of water-quality conditions in the SJR is inadequate to ascertain if progress is being made towards either limiting loading of Se, meeting the water-quality objectives, or protecting the SJR (Westcot, et al., 1996; Presser and Piper, 1998). The models are conservative-element dilution models that have not considered the potential for Se to accumulate in sediment or bioaccumulate in biota (Environmental Defense Fund, 1994; Karkoski, 1996). The assimilative capacity for the SJR in existing models is defined only by flow (i.e., dilution capacity). In one derivation of the TMDL model, acknowledgement is made of the shortcomings of the approach by stating that, if in the future load limits are derived based on the capacity of the ecosystem to safely absorb pollutants, the methodology to derive the load allowances would change, but the implementation issues for the agricultural dischargers would remain the same (Environmental Defense Fund, 1994). Implementation issues may include an economic justification of continued impairment of the SJR's beneficial uses required by anti-degradation policies (Code of Federal Regulations 40:131.12; Clean Water Act Section 303(d) as amended, 1987). Hydrologic-economic models for the SJV and information regarding the cost/benefit of agriculture in the SJV have been developed and compiled at various stages of planning for irrigation and drainage projects (e.g., SJV Interagency Drainage Program, 1979a; b; CDWR, 1982; Horner, 1986; Willey, 1990; Dinar and Zilberman, 1991; Environmental Defense Fund, 1994; CCVRWQCB, 1996c). Monthly Se concentrations greater than 5 µg/L have not occurred further downstream in the SJR at Vernalis, the entrance to the Bay-Delta.

Models that Target Load Reduction

Models were constructed in 1994 to target the load of Se that might be discharged to the SJR with the goal of meeting a federal 5 µg Se/L concentration standard and a state 8 µg Se/L concentration objective. USEPA rejected the 8 µg Se/L objective for the SJR in 1992 and promulgated a 5 µg Se/L standard for the SJR and a 2 µg Se/L standard for associated wetland channels (i.e., wildlife refuge supply channels) (USEPA, 1992). A TMDL model was developed by the Environmental Defense Fund and an alternative model named the Total Maximum Monthly Load (TMML) model was developed in conjunction with the state (CCVRWQCB, 1994b; Environmental Defense Fund, 1994). The Environmental Defense Fund model was a test case for agricultural non-point source pollution control that applies point source control regulation methodology. The model focuses on pollution sources, a program of load reductions, and economic incentives which include tradable discharge permits and tiered water pricing (Environmental Defense Fund, 1994). The modified version of the TMDL model for the SJR was adopted as part of a *waste discharge permit* for the Grassland subarea in 1998 (CCVRWQCB, 1998a).

The choice of a compliance site for the models and the waste discharge permit has critical implications for the perception of water quality in the SJR. Little fresh water flows into the SJR upstream of Crows Landing due to regulation of the SJR by Friant Dam. Most of the SJR is diverted south through the Friant-Kern Canal, leaving agricultural drainage as the majority of the flow in the SJR heading north in the 22 miles of river above confluence with the Merced River. A compliance site upstream of the Merced River would be the most precautionary. It would closely reflect the quality of the drainage water and be indicative of conditions in the upstream 22 miles. Compliance at the site below the confluence with the Merced River is influenced by the dilution water provided by the Merced River. This site is probably more indicative of downstream water quality. The current compliance point is the SJR downstream the Merced River at Crows Landing. It represents the 130-mile reach of the lower SJR that is listed as impaired. The state permit for discharge to the SJR allows for a twelve-year compliance schedule. Full compliance for the SJR above and below the Merced River to a Se water-quality objective of 5 μg/L (4-day average) is scheduled for October 2010.

Variables considered in deriving a Se load allocation from the TMDL-type models are:

- water-year type,
- water-quality objective,
- averaging period,
- exceedance frequency, and
- flow derivation.

Table C1 and Figures C2, C3 and C4 give a summary of volume of discharge and loads to compare example load allocations from the TMDL and the TMML models for different types of water years. Figure C2 shows the TMDL model loads for all water-year types (normal/wet, dry/below normal, and critically dry) for the case of a 5 μg Se/L standard, 4-day average, and a one-in-three-year violation rate. Figure C3 shows a comparison of the TMDL and TMML model loads for a wet-year allocation under the same conditions as above. Figure C4 shows a comparison of the TMDL and TMML model loads for a dry-year allocation under the same conditions as above. Tables C2 and C3 and Figures C5 through C10 document in more detail the load allocations for the SJR calculated from several different combinations of model assumptions using a Se water-quality objective of 8 or 5 μg/L. These data are compiled from documentation for the TMDL and TMML models (CCVRWQCB, 1994b and Environmental Defense Fund, 1994).

The base case for the SJR TMDL was a single design flow of approximately 92,000 acre-feet at 5 μg Se/L. The model allocated a load of 1,248 lbs Se (Table C2) (Environmental Defense Fund, 1994). The quasi-static type TMDL model has three water-year classifications for the SJR (critically dry, dry/below normal, and above normal/wet; Table C2 and Figures C5, C6, and C7). The TMML model, as submitted to USEPA for approval, derives loads for only two types of water years (critically dry/dry/below normal and above normal/wet; Table C3 and Figures C8, C9, and C10). Figures C5 through C10 also depict the seasonal nature of the models, with the greatest loads being discharged from December through May. Within a specific model, greater loads are allowed when dry-year water-years are replaced by wet-year water-years. Load allocations also increase when 4-day averages are replaced by monthly averages, and when allowable frequencies of violations of once-in-three-years are replaced by a frequency of once-in-five-months (Figures C5 through C10). The TMDL model allows annual discharges to the SJR at Crows Landing/Patterson of 1,394 to 4,458 lbs Se in dry years (i.e., critically dry, dry, and below normal years – Table C1) within the ranges of options and excursion frequencies. The TMML allows discharges of 1,240 to 1,809 lbs Se/year in dry years. In wet years the TMDL model allows loads of 3,165 to 6,547 lbs Se/year and the TMML model predicts loads of 3,760 to 5,334 lbs Se/year.

The Clean Water Act requires a *margin of safety* be considered in regulatory load models based solely on dilution. The purpose is to take into account any lack of knowledge concerning the relation of effluent limitations and water quality (Environmental Defense Fund, 1994). Tables C1, C2, and C3 also show Se loads used as a nominal 10% margin of safety to account for the uncertainties in the data and as estimated background loads from tributary rivers and wetlands. The margin of safety ranges from 123 to 448 lbs Se/year in dry years and 317 to 534 lbs Se/year in wet years. Background loads range from 91 to 273 lbs Se/year in dry years and 250 to 428 lbs Se/year in wet years. These loads were added to the modeled TMDL allowances for the dischargers, thereby increasing the modeled discharge to the SJR at Crows Landing (Tables C1, C2, and C3), but leaving in doubt protection of the SJR.

Models that Maximize the Allowed Selenium Load by Targeting Concentration

An alternative approach is to define a concentration target in a receiving water and manage Se discharges to maintain that target concentration under different flow conditions. Such a model, designed to manage loads using *dynamic* drainage effluent limits based on the *real-time* dilution capacity of the SJR, was recently suggested as a drainage management tool (Karkoski, 1996; CSWRCB, 1999a). In this proposal, Se-load-reduction is deferred to a plan of temporal storage and timed release of concentrated effluent to match dilution by tributary flows to obtain compliance to the 5 μg Se/L objective. The dynamic real-time (DRT) model, thus, uses timed-release of Se-laden drainage to take maximum advantage of the dilution capacity of the river at the given water-quality objective (e.g., the Se concentration in the SJR will be maintained at 5 μg Se/L at all times). Figure C11 shows an example from limited data of the DRT model loads for wet-year conditions using a 5 μg Se/L objective (Karkoski, 1996). Table C1 compares the loadings allowed by the DRT model to those allocated by the TMDL and TMML models, for a minimum, mean, and maximum amount of allowable loads of Se discharged per month in a wet year. Figure C11 shows that an order-of-magnitude higher loads occurs in some months than allowed by the TMDL or TMML models (e.g., 400 versus 4000 lbs Se) for some months. The DRT approach uses short-term forecasts of flow and salt concentration. The loads discharged for a wet year range from 2,605 to 17,605 lbs Se/year, with a mean of 7,347 lbs Se/year. A more recent reference to the DRT model shows the wet year load to be approximately that referenced in 1996 for a wet year (7,401 lbs Se/year) and a dry year value of 4,631 lbs Se/year (SJV Drainage Implementation Program, 1999b). With real-time drainage management, ponds for flow regulation would be necessary in order to maximize release of Se loads during variable flow conditions in the river. The holding pond concept is reminiscent of planning for the SLD in the 1970's when Kesterson Reservoir ponds were to be used as holding reservoirs to regulate flows until the SLD was completed to the Bay-Delta. As mentioned earlier, more sophisticated storage, control, and timing are envisioned by managers and state regulators. Nevertheless, the ecological consequences of the ponds themselves need to be considered.

Managing a constant concentration in receiving waters, although in response to a TMDL requirement, is the goal of the dynamic-effluent-type of modeling. It is unclear whether this deviation from the load model target was the intended use of the concentration-dependent water-quality standards defined by USEPA. The DRT approach uses a receiving water body's capacity to provide dilution water to maximize disposal of Se. Regulation of loads based on dynamic effluent limits provides no certainty for the amount discharged per month or year, nor for an assessment of the long-term progress toward Se load reduction. The focus of the TMDL and TMML models is to reduce or minimize Se loads by establishing a load target. With real-time drainage management, the focus is shifted to a concentration target that, in essence, maximizes Se loads by adjusting the timing of discharges to coincide with dilution capacity. As a result the allowed Se load would increase over those allocated by the TMDL or TMML models. The DRT approach is best applied to maintaining the designated level of quality in the SJR as a receiving water. It is of less value in regulating the SJR as a source water for the Bay-Delta.

Some additional practical considerations add complexity to applying the DRT concept. These include the fact that a regulatory authority for the responsibility of implementing *real time* regulation has not been identified. Uncertainty exists about the regulatory control program that would determine the target concentration. Different agencies and stakeholders have called for revisions of the Se objective upward from 5 μg Se/L, upward to 8 μg Se/L, or downward to 2 μg Se/L. The choice of a compliance point (SJR at Patterson or Crows Landing or SLD at Mud Slough) will have a strong influence on objectives, and therefore, it is also critical to determining the allowed load (as described above). Uncertainties about the use of the conveyance channel for the drainage (wetland channels or the SLD) could have implications for concentrations. Since agricultural drainage is regulated as non-point source pollution, a 5 μg Se/L effluent stream from the discharger has not been required in the past. It is unclear how this would be integrated into the regulatory control program. Finally, refinement of the assimilative capacity operations plan using real-time management does not include collecting data to assess whether re-defining the assimilative capacity of the SJR based on the bioaccumulative nature of Se is necessary (GAF, 1998a). Understanding the sources of Se and how Se moves through the agricultural discharge system becomes very important in a strategy that maximizes loads to meet concentration objectives.

A second reason for modeling the influence of timed releases of agricultural discharges to the SJR has been to meet the salinity standard for the SJR at Vernalis (CSWRCB, 1994, 1997, and 1999a; EA Engineering, Science, and Technology, 1999). The state model predicted that controlled timing or wetland releases or a combination of drainage and wetland releases did not obtain compliance with that standard. Focus then shifted toward taking advantage of additional seasonally available downstream dilution by releasing dilution water from the New Melones Reservoir on the Stanislaus River. Control of drainage release to the SJR also includes implementation of a system of storage including recycling facilities, evaporation ponds, and in-field subsurface storage (CSWRCB, 1997). Despite the several opportunities for manipulating the massively engineered CVP water supply, the ultimate alternative for salinity control seems to depend on managing the same lands that need drainage and that discharge Se, but the state plan does not include an analysis of Se impacts.

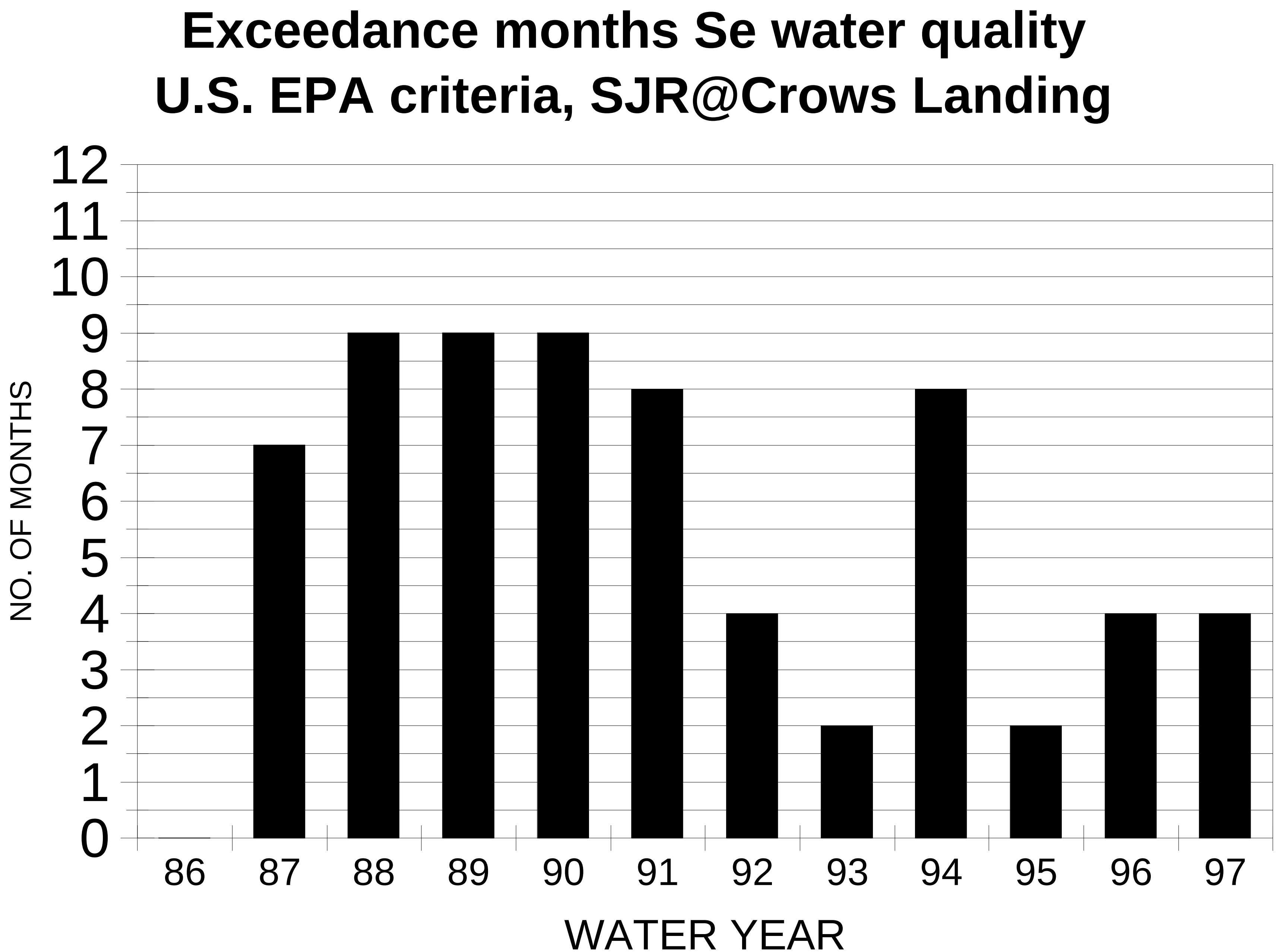

Exceedance months Se water quality
U.S. EPA criteria, SJR@Crows Landing
NO. OF MONTHS
0
1
2
3
4
5
6
7
8
9
10
11
12
86
87
88
89
90
91
92
93
94
95
96
97
WATER YEAR

Figure C1

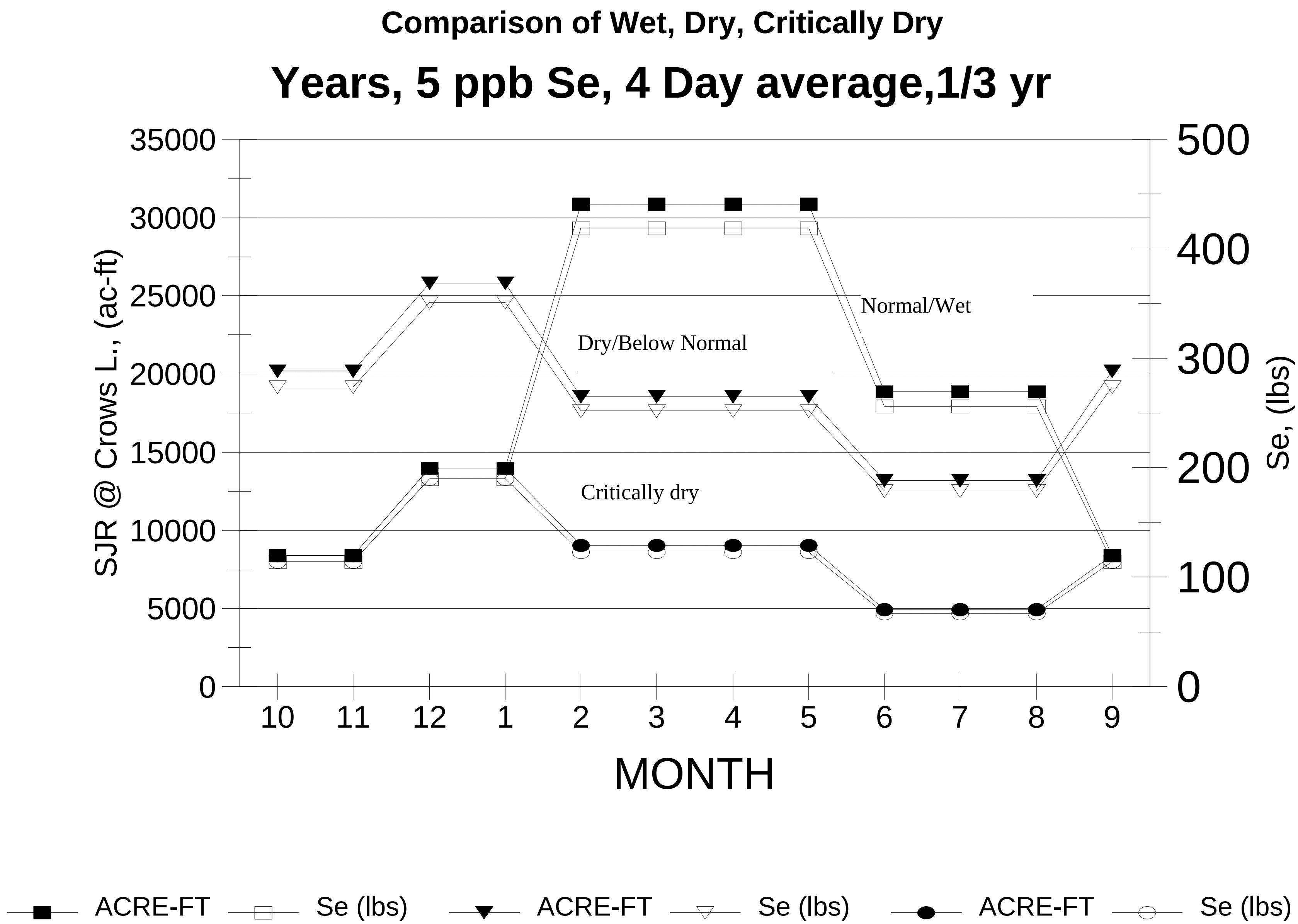

Comparison of Wet, Dry, Critically Dry
Years, 5 ppb Se, 4 Day average,1/3 yr
SJR @ Crows L., (ac-ft)
35000
30000
25000
20000
15000
10000
5000
0
Se, (lbs)
500
400
300
200
100
0
Normal/Wet
Dry/Below Normal
Critically dry
10
11
12
1
2
3
4
5
6
7
8
9
MONTH
ACRE-FT
Se (lbs)
ACRE-FT
Se (lbs)
ACRE-FT
Se (lbs)

Figure C2

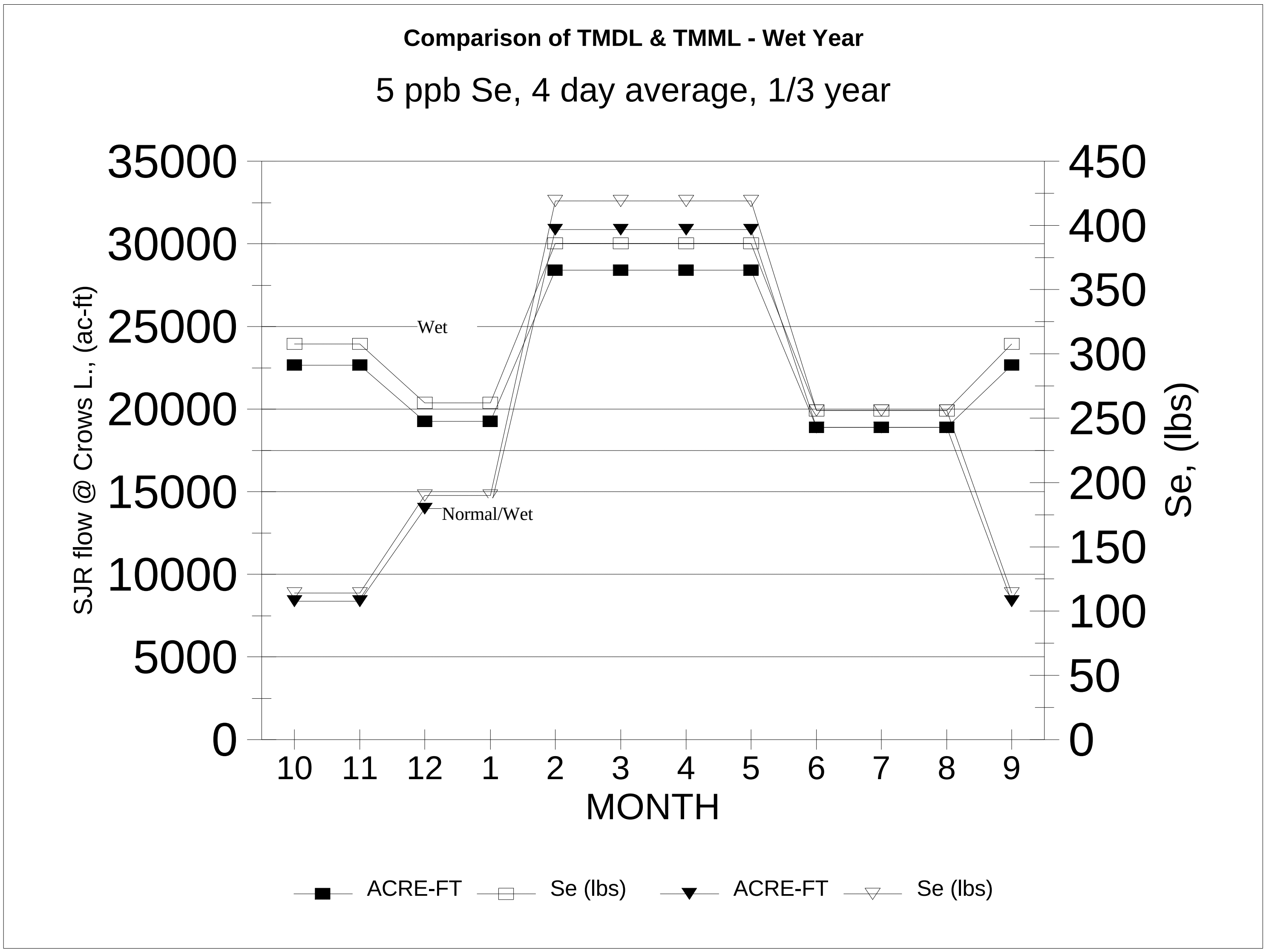

Comparison of TMDL & TMML - Wet Year
5 ppb Se, 4 day average, 1/3 year
SJR flow @ Crows L., (ac-ft)
Se, (lbs)
35000
30000
25000
20000
15000
10000
5000
0
450
400
350
300
250
200
150
100
50
0
Wet
Normal/Wet
10
11
12
1
2
3
4
5
6
7
8
9
MONTH
ACRE-FT
Se (lbs)
ACRE-FT
Se (lbs)

Figure C3

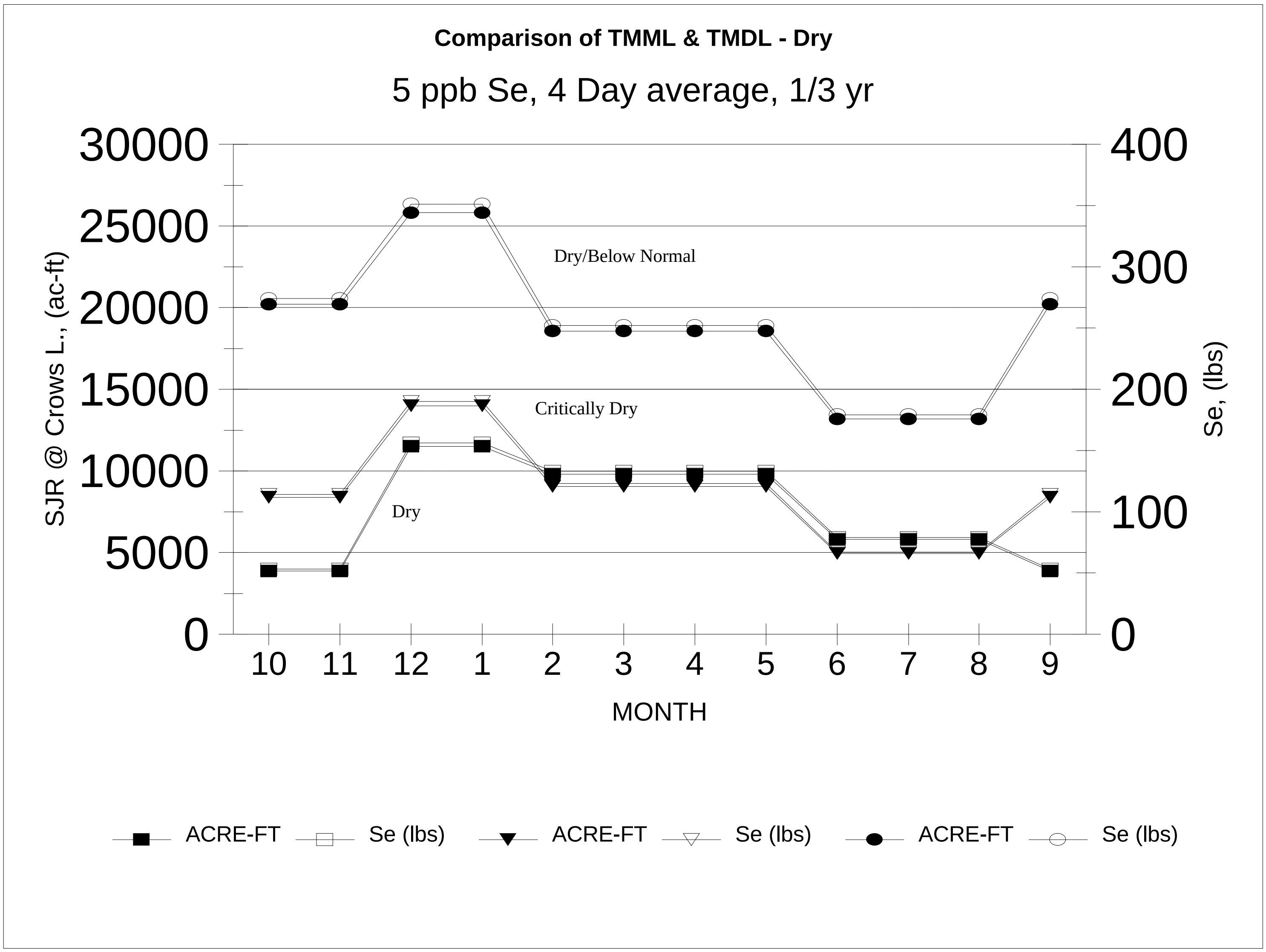

Comparison of TMML & TMDL - Dry
5 ppb Se, 4 Day average, 1/3 yr
SJR @ Crows L., (ac-ft)
Se, (lbs)
30000
25000
20000
15000
10000
5000
0
400
300
200
100
0
Dry/Below Normal
Critically Dry
Dry
10
11
12
1
2
3
4
5
6
7
8
9
MONTH
ACRE-FT
Se (lbs)
ACRE-FT
Se (lbs)
ACRE-FT
Se (lbs)

Figure C4

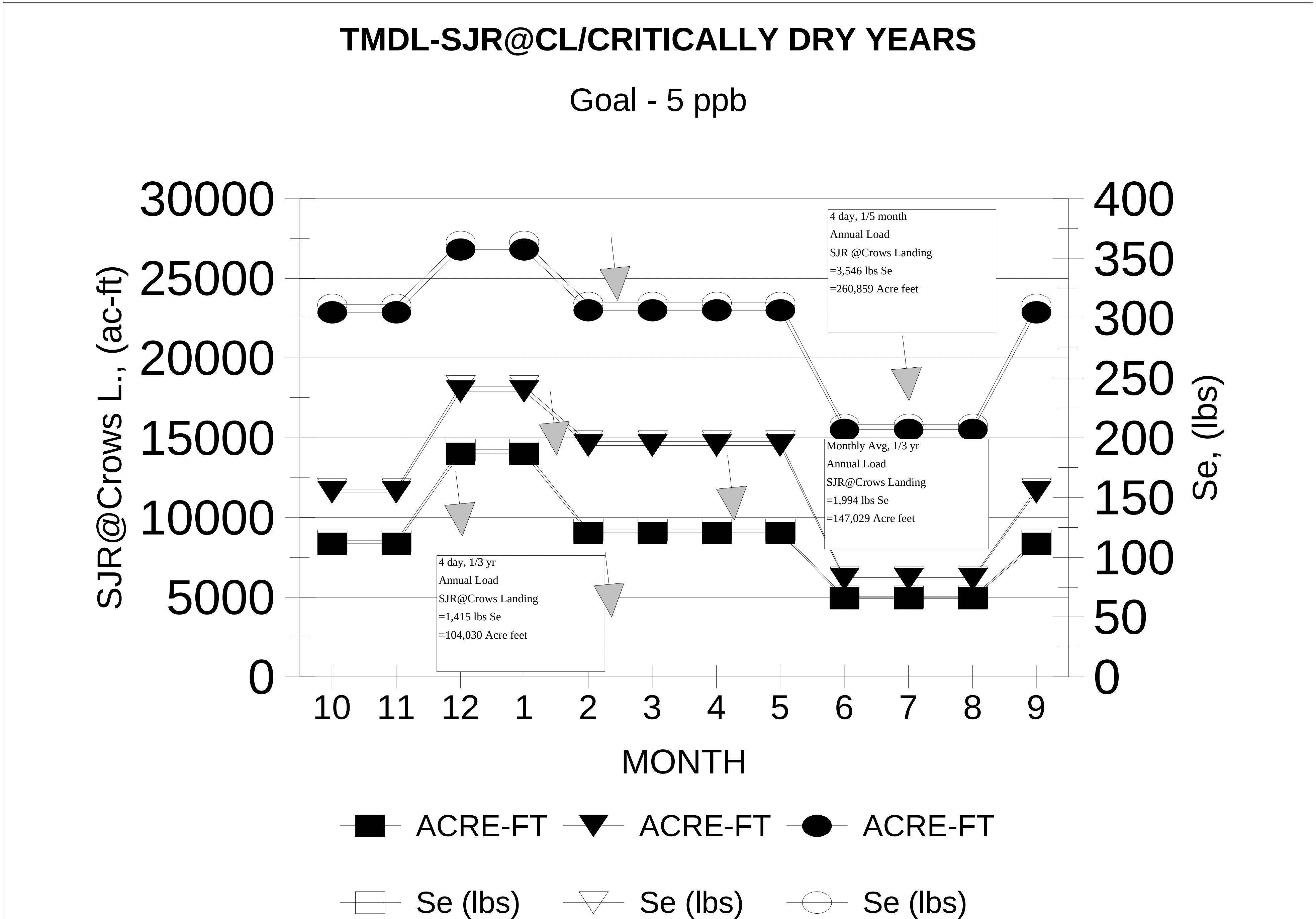

TMDL-SJR@CL/CRITICALLY DRY YEARS
Goal - 5 ppb
SJR@Crows L., (ac-ft)
Se, (lbs)
30000
25000
20000
15000
10000
5000
0
400
350
300
250
200
150
100
50
0
10
11
12
1
2
3
4
5
6
7
8
9
MONTH
4 day, 1/5 month
Annual Load
SJR @Crows Landing
=3,546 lbs Se
=260,859 Acre feet
Monthly Avg, 1/3 yr
Annual Load
SJR@Crows Landing
=1,994 lbs Se
=147,029 Acre feet
4 day, 1/3 yr
Annual Load
SJR@Crows Landing
=1,415 lbs Se
=104,030 Acre feet
ACRE-FT
ACRE-FT
ACRE-FT
Se (lbs)
Se (lbs)
Se (lbs)

Figure C5

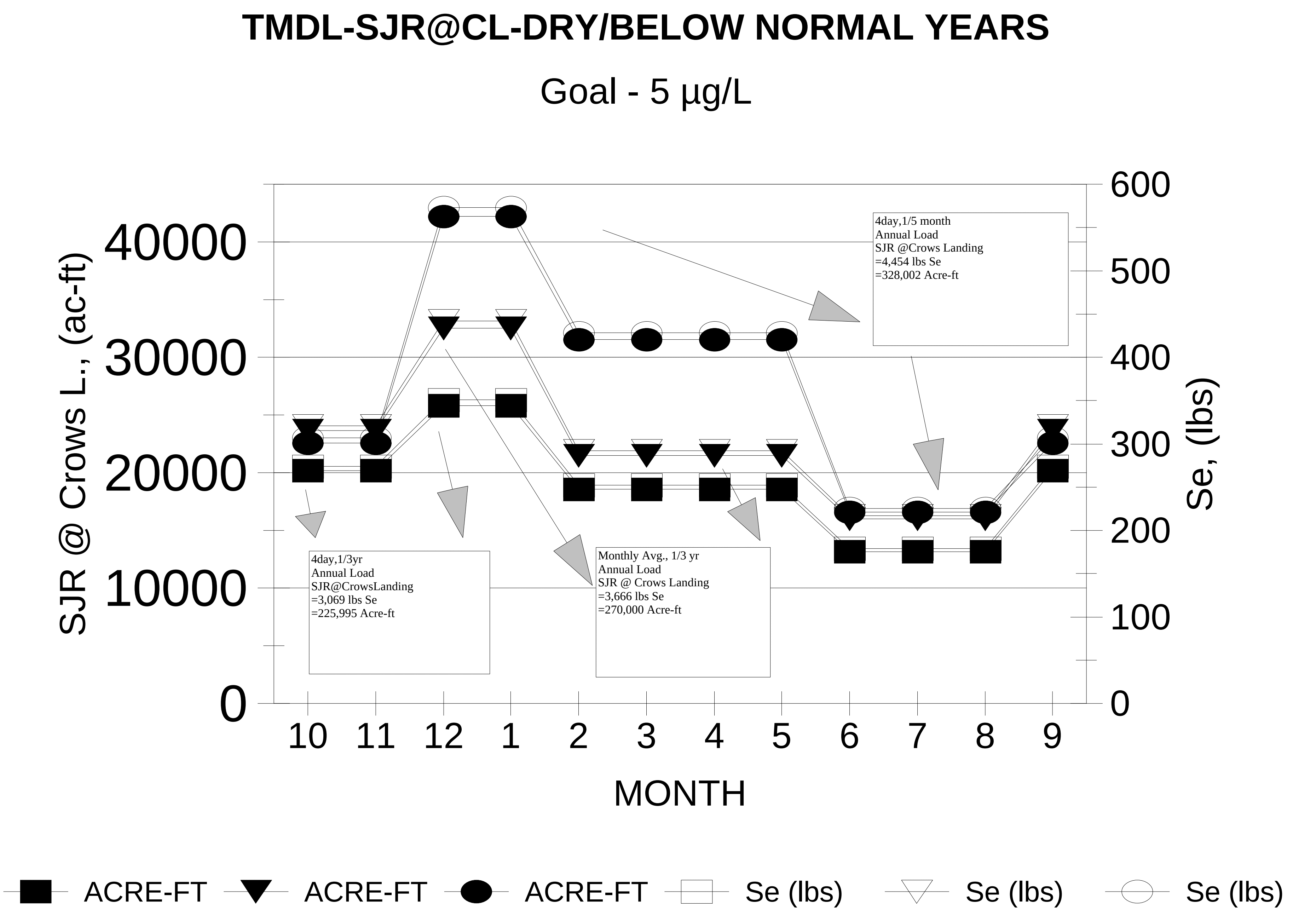

TMDL-SJR@CL-DRY/BELOW NORMAL YEARS
Goal - 5 µg/L
SJR @ Crows L., (ac-ft)
0
10000
20000
30000
40000
Se, (lbs)
0
100
200
300
400
500
600
MONTH
10
11
12
1
2
3
4
5
6
7
8
9
4day,1/5 month
Annual Load
SJR @Crows Landing
=4,454 lbs Se
=328,002 Acre-ft
4day,1/3yr
Annual Load
SJR@CrowsLanding
=3,069 lbs Se
=225,995 Acre-ft
Monthly Avg., 1/3 yr
Annual Load
SJR @ Crows Landing
=3,666 lbs Se
=270,000 Acre-ft
ACRE-FT
ACRE-FT
ACRE-FT
Se (lbs)
Se (lbs)
Se (lbs)

Figure C6

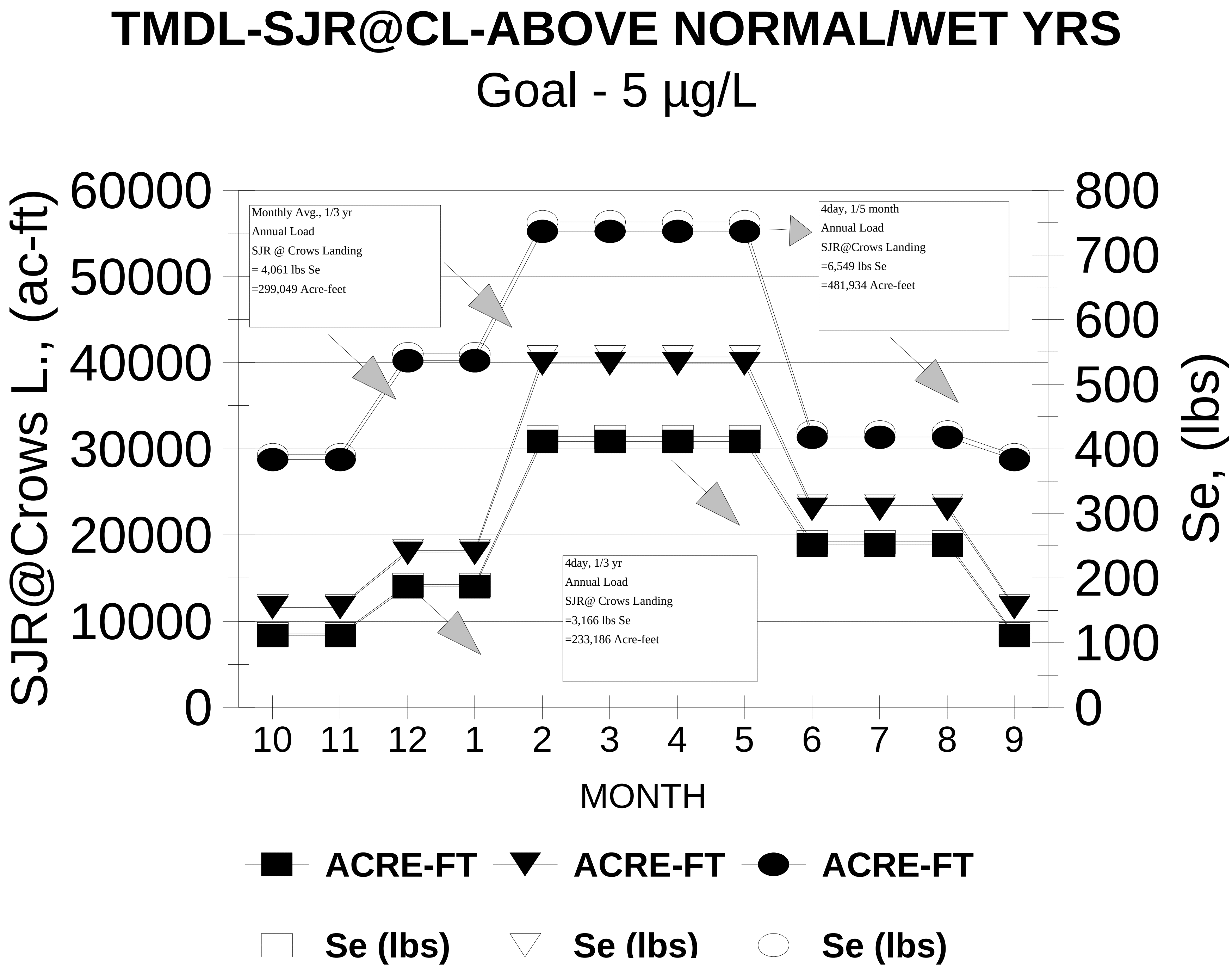
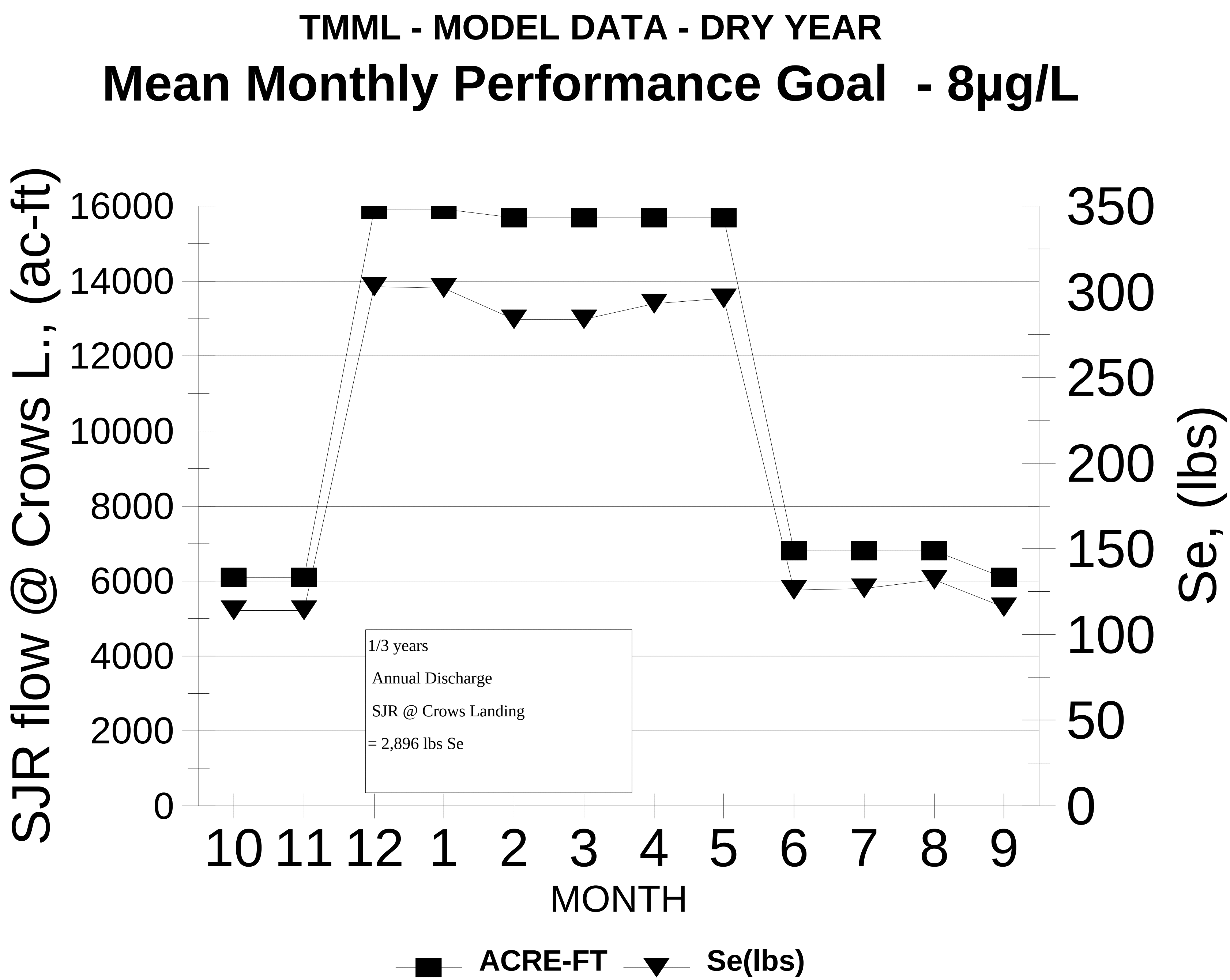

TMDL-SJR@CL-ABOVE NORMAL/WET YRS
Goal - 5 µg/L
SJR@Crows L., (ac-ft)
Se, (lbs)
MONTH
Monthly Avg., 1/3 yr
Annual Load
SJR @ Crows Landing
= 4,061 lbs Se
=299,049 Acre-feet
4day, 1/5 month
Annual Load
SJR@Crows Landing
=6,549 lbs Se
=481,934 Acre-feet
4day, 1/3 yr
Annual Load
SJR@ Crows Landing
=3,166 lbs Se
=233,186 Acre-feet
ACRE-FT
ACRE-FT
ACRE-FT
Se (lbs)
Se (lbs)
Se (lbs)

Figure C7



TMML - MODEL DATA - DRY YEAR
Mean Monthly Performance Goal - 8µg/L
SJR flow @ Crows L., (ac-ft)
16000
14000
12000
10000
8000
6000
4000
2000
0
Se, (lbs)
350
300
250
200
150
100
50
0
10 11 12 1 2 3 4 5 6 7 8 9
MONTH
1/3 years
Annual Discharge
SJR @ Crows Landing
= 2,896 lbs Se
ACRE-FT
Se(lbs)

Figure C8

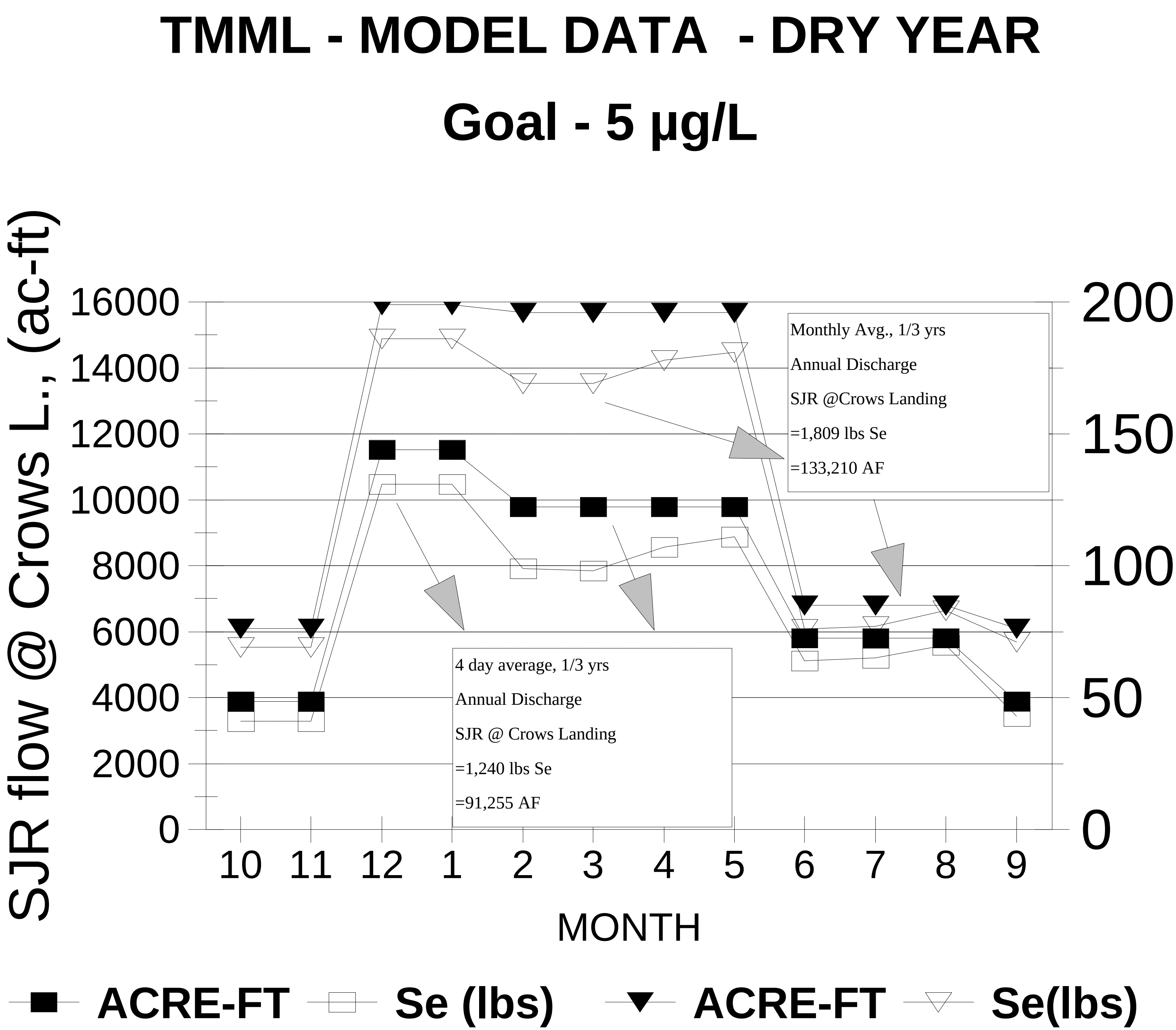
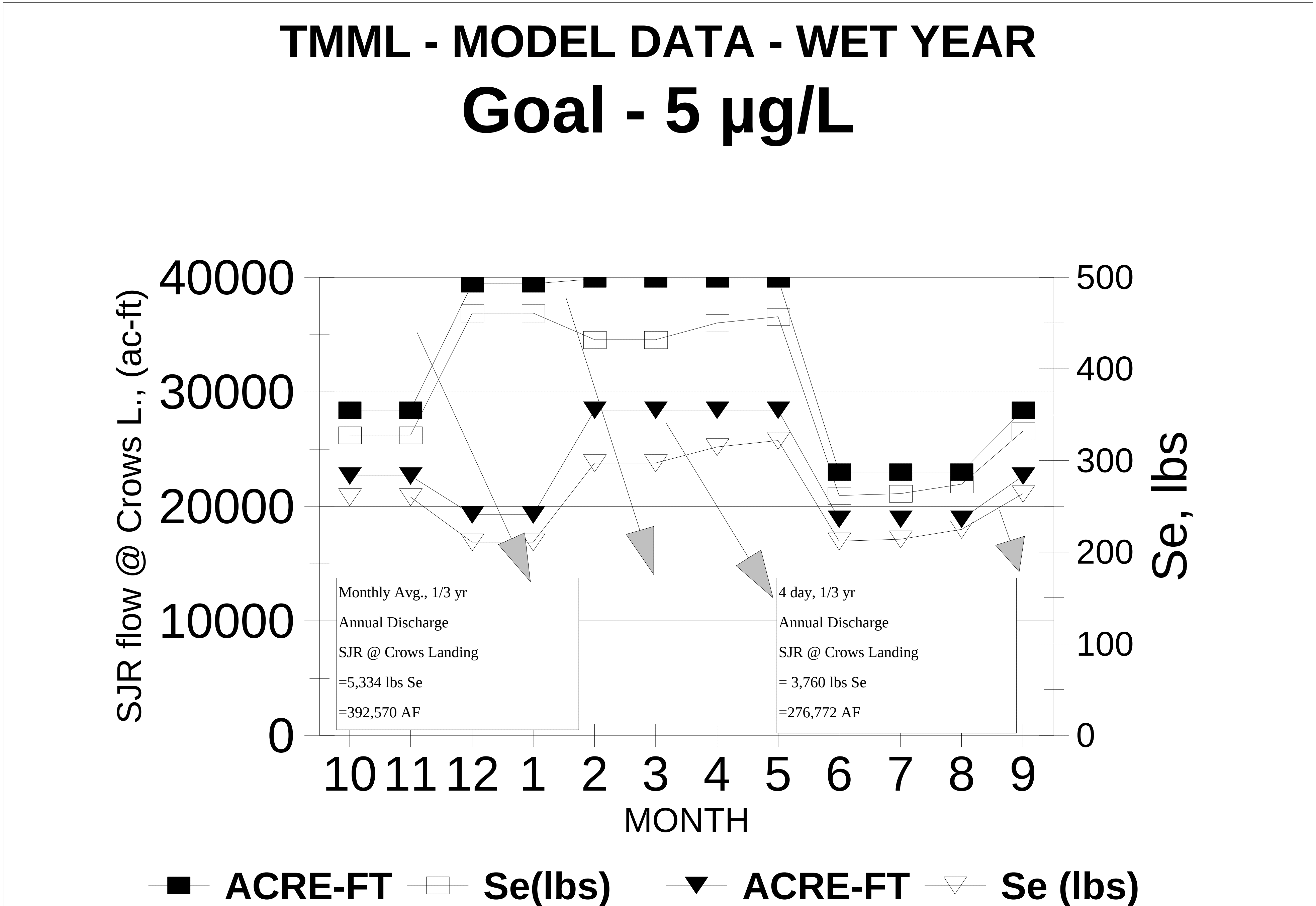

TMML - MODEL DATA - DRY YEAR
Goal - 5 µg/L
SJR flow @ Crows L., (ac-ft)
Se, (lbs)
MONTH
16000
14000
12000
10000
8000
6000
4000
2000
0
200
150
100
50
0
10
11
12
1
2
3
4
5
6
7
8
9
Monthly Avg., 1/3 yrs
Annual Discharge
SJR @Crows Landing
=1,809 lbs Se
=133,210 AF
4 day average, 1/3 yrs
Annual Discharge
SJR @ Crows Landing
=1,240 lbs Se
=91,255 AF
ACRE-FT
Se (lbs)
ACRE-FT
Se(lbs)

Figure C9



TMML - MODEL DATA - WET YEAR
Goal - 5 µg/L
SJR flow @ Crows L., (ac-ft)
Se, lbs
40000
30000
20000
10000
0
500
400
300
200
100
0
10 11 12 1 2 3 4 5 6 7 8 9
MONTH
Monthly Avg., 1/3 yr
Annual Discharge
SJR @ Crows Landing
=5,334 lbs Se
=392,570 AF
4 day, 1/3 yr
Annual Discharge
SJR @ Crows Landing
= 3,760 lbs Se
=276,772 AF
ACRE-FT
Se(lbs)
ACRE-FT
Se (lbs)

Figure C10

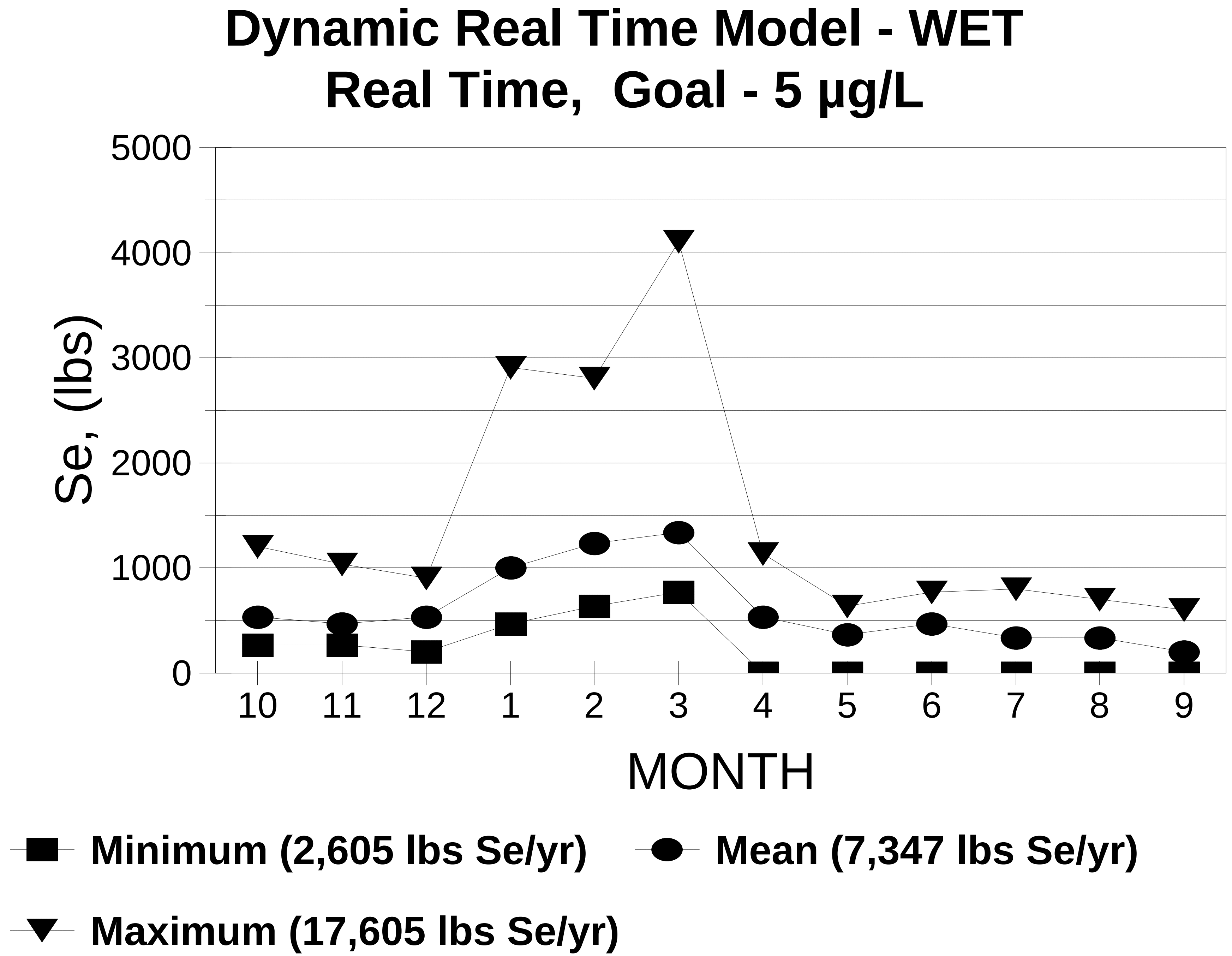

Dynamic Real Time Model - WET
Real Time, Goal - 5 µg/L
Se, (lbs)
5000
4000
3000
2000
1000
0
10
11
12
1
2
3
4
5
6
7
8
9
MONTH
Minimum (2,605 lbs Se/yr)
Mean (7,347 lbs Se/yr)
Maximum (17,605 lbs Se/yr)

Figure C11

Table C1 Modeled Selenium Load Allocation and Discharge to the San Joaquin River from the Grassland Drainage Problem Area

Models	**Irrigated/ drained acres**	**Range used to model Se discharge (San Joaquin River at Crows Landing) (acre-feet/year)**	**Range of modeled Se load allocation (lbs Se/year)**	**Range of Modeled Se background (lbs/Se/year)**	**Range of modeled Se MOS (margin of safety) (uncertainty) (lbs Se/year)**	**Range of modeled Se discharge to San Joaquin River at Crows Landing (lbs Se/year)**
Total Maximum Daily Load (TMDL)*	93,390/					
(5 ppb Se objective in San Joaquin	49,273					
River						
4-day or monthly averaging period						
1in 3 year or 1 in 5 month violation						
frequency)		104,030-260,859	1,163-3,060	91-129	140-352	1,394-3,541
Critically Dry**		225,995-328,002	2,504-3,737	257-273	305-448	3,066-4,458
Dry/Below Normal**		233,186-481,934	2,598-5,463	250-428	317-656	3,165-6,547
Above Normal/Wet**						
Total Maximum Monthly Load	90,620/					
(TMML)***	44,860					
(5 ppb Se objective in San Joaquin						
River						
4-day or monthly averaging period		91,255-133,210	1,001-1,514	116-114	123-179	1,240-1,809
1in 3 year violation frequency)		276,772-392,570	3,088-4,451	294-362	381-534	3,760-5,334
Dry						
Wet						
Dynamic Real Time (DRT) ******						
5 ppb Se objective in San Joaquin						
River			2,605-17,605			
Wet			(7,347 mean)			

* Environmental Defense Fund, 1994; CCVRWQCB, 1994b;

**Critically Dry < 2.1MAF; dry 2.1-2.5 MAF; Below Normal 2.5-3.1 MAF; Above Normal 3.1-3.8 MAF; and Wet >3.8 MAF (CCVRWQCB, 1994b, Table 7); reference to San Joaquin River Index , threshold millions of acre-feet (CCVRWQCB, 1994b);

*** Draft Submittal to USEPA from CCVRWQCB, 1996a;

**** Karkoski, 1996 (calculated effluent limits for wet years based on 22 year period of record).

Table C2 Modeled (TMDL, Total Maximum Daily Load model) Annual Selenium Load Allowance to the San Joaquin River from the Grassland Area

Selenium Performance Goal or Regulation Scenario	Irrigated acreage/drained acreage****	Modeled load allocation lbs Se/year	Modeled background lbs Se/year	Modeled MOS (Margin of Safety) (Uncertainty) lbs Se/year	Modeled discharge to San Joaquin River at Crows Landing/ Patterson lbs Se/year	Modeled flow (San Joaquin River at Crows Landing/ Patterson) (acre-feet/year)
TMDL Model* Single design flow 5 ppb Se 4-day average 1 in 3 yr violation frequency	93,390/49,273	1,248				92,363
TMDL Model 5 ppb Se 4-day average 1 in 3 yr violation frequency						
Critically Dry	93,390/49,273	1,163	110	140	1,415	104,030
Dry/Below Normal		2,504	257	305	3,069	225,995
Above Normal/Wet		2,598	250	317	3,166	233,186
TMDL Model 5 ppb Se monthly average 1 in 3 yr violation frequency						
Critically Dry	93,390/49,273	1,676	119	200	1,994	147,029
Dry/Below Normal		3,036	265	366	3,666	270,000
Above Normal/Wet		3,374	280	405	4,061	299,049
TMDL Model 5 ppb Se 4-day average 1 in 5 month violation frequency						
Critically Dry	93,390/49,273	3,060	129	352	3,546	260,859
Dry/Below Normal		3,737	273	448	4,454	328,002
Above Normal/Wet		5,463	428	656	6,549	481,934

* Developed by Environmental Defense Fund (EDF, 1994) and CCVRWQCB, 1994b)
** Draft submittal of TMML Model for Selenium in the San Joaquin River to USEPA (CCVRWQCB, 1996a)
*** Modeled effluent load data from October, 1985 to December, 1988; modeled San Joaquin River flow at Crows Landing and Patterson from WY 1970 to 1991 (Notes: Flow record for Crows Landing is from 1970-1972; the remainder of the data used in the model for Crows Landing was reconstructed from flow data collected at SJR at Patterson. Data was also "adjusted" for averaging period because record is incomplete, CCVRWQCB, 1994 b; Karkoski, 1996)
**** Environmental Defense Fund, 1994, Table II-4 Baseline Data for Pollution Allocation Subtotal (does not include 10,000 irrigated acres and 5,276 drained acres as noted in Total) taken from water district data for various years (1987-1990) and CCVRWQCB data.
*****Critically Dry < 2.1MAF; dry 2.1-2.5 MAF; Below Normal 2.5-3.1 MAF; Above Normal 3.1-3.8 MAF; and Wet >3.8 MAF (CCVRWQCB, 1994b, Table 7)

Table C3 Modeled (TMML model, Total Maximum Monthly Load model and DRT model, Dynamic Real-Time model) Annual Selenium Load Allowance to the San Joaquin River from the Grassland Area

Selenium Performance Goal or Regulation Scenario	Irrigated acreage/drained acreage****	Modeled load allocation lbs Se/year	Modeled background lbs Se/year	Modeled MOS (Margin of Safety) (Uncertainty) lbs/year	Modeled discharge to San Joaquin River at Crows Landing/ Patterson lbs Se/year	Modeled flow (San Joaquin River at Crows Landing/ Patterson) acre-feet/year
TMML Model* 8 ppb Se monthly mean 1 in 3 yr violation frequency critically dry/dry/below normal	90,620/44,860	2,491	114	290	2,896	133,210
TMML Model 5 ppb Se 4-day average 1 in 3 yr violation frequency critically dry/dry/below normal above normal/wet	90,620/44,860	1,001 3,088	116 294	123 381	1,240 3,760	91,255 276,772
TMML Model 5 ppb Se monthly average 1 in 3 yr violation frequency critically dry/dry/below normal above normal/wet	90,620/44,860	1,514 4,451	114 362	179 534	1,809 5,334	133,210 392,570
DRT Model 5 ppb Se wet mean minimum maximum**		7,347 2,605 17,605				

* Draft submittal of TMML Model for Selenium in the San Joaquin River to USEPA (CCVRWQCB, 1996a);

** Karkoski, 1996;

*** Modeled effluent load data from October, 1985 to December, 1988; model San Joaquin River flow at Crows Landing and Patterson from WY 1970 to 1991 (Note: flow record for Crows Landing is from 1970-1972. The remainder of the data used in the model for Crows Landing was reconstructed from flow data collected at SJR at Patterson);

****CCVRWQCB, 1994b, Table 1.

APPENDIX D

Variability

APPENDIX D

Variability

CONTENTS

FIGURES

D21. San Luis Drain Special Study. Hourly relations between electrical conductance (µmhos) and selenium concentrations (µg Se/L) during 1 – 24 hour period (6/26/97).

D22. Relation between selenium load (lbs) and selenium concentrations (µg Se/L) at Crows Landing for WY 1997.

D23. Relation between selenium load (lbs) and selenium concentrations (µg Se/L) at Crows Landing for WY 1998.

D24. Relation between salt load (tons) and salt concentration (mg/L) at Crows Landing for WY 1997.

D25. Relation between salt load (tons) and salt concentration (mg/L) at Crows Landing for WY 1998.

D26. Continuous flow monitoring (cfs) at Crows Landing for WY 1997.

D27. Continuous selenium concentration monitoring (µg Se/L) at Crows Landing for WY 1997.

D28. Continuous specific conductance monitoring (µS/cm) at Crows Landing for WY 1997.

D29. Calculated total dissolved solids (mg/L salt) at Crows Landing for WY 1997.

D30. Continuous selenium load monitoring (lbs) at Crows Landing for WY 1997.

D31. Calculated salt (tons/day) at Crows Landing for WY 1997.

D32. Continuous flow monitoring (cfs) at Crows Landing for WY 1998.

D33. Continuous selenium concentration monitoring (µg Se/L) at Crows Landing for WY 1998.

D34. Continuous specific conductance monitoring (µS/cm) at Crows Landing for WY 1998.

D35. Calculated total dissolved solids (mg/L salt) at Crows Landing for WY 1998.

D36. Continuous selenium load monitoring (lbs) at Crows Landing for WY 1998.

D37. Calculated salt load (tons/day) at Crows Landing for WY 1998.

D38. Percent selenium load (normalized to the selenium load at Vernalis) for Drainage Problem Area (DPA), Mud Slough + Salt Slough (MS+SS), and Crows Landing-Patterson (CL-PATT) for WY 1986 through WY 1997.

D39. Percent salt load (normalized to the salt load at Vernalis) for Drainage Problem Area (DPA), Mud Slough + Salt Slough (MS+SS), and Crows Landing-Patterson (CL-PATT) for WY 1986 through WY 1997.

D40. Relation between total water applied (acre-feet) and drainage flow (acre-feet) for the Drainage Problem Area (DPA) for WY 1986 through WY 1997.

D41. Relation between total water applied (acre-feet), total dissolved solids (mg/L), and selenium (µg Se/L) for the Drainage Problem Area (DPA) for WY 1986 through WY 1997.

D42. Relation between total water applied (acre-feet), total dissolved solids loads (tons), and selenium load (lbs) for the Drainage Problem Area (DPA) for WY 1986 through WY 1997.

D43. Relation between drainage flow (acre-feet), selenium (µg Se/L), and total dissolved solids (mg/L) for the Drainage Problem Area (DPA) for WY 1986 through WY 1997.

D44. Relation between drainage flow (acre-feet), selenium load (lbs), and total dissolved solids load (tons) for the Drainage Problem Area (DPA) for the WY 1986 through WY 1997.

D45. Relation between 1) flow and selenium load and 2) between flow and selenium concentration at site B (SLD outflow to Mud Slough) for WY 1997.

D46. Relation between 1) flow and selenium load and 2) between flow and selenium concentration at site B (SLD outflow to Mud Slough) for WY 1998.

D47. Monthly relation between drainage discharge (acre-feet), irrigation + precipitation (acre-feet), and selenium concentration of drainage (µg Se/L) at site B for WY 1997.

D48. Monthly relation between drainage discharge (acre-feet), irrigation + precipitation (acre-feet),

TABLES

APPENDIX D

Variability

Introduction

The above estimates of loadings contain some substantial uncertainties that have not been discussed. The most important of these are associated with the time dependence and the spatial dependence of Se loads or the ways those loads are determined. Given here are a series of graphs (Figures D1 through D56) based on available data that document the variability of agricultural drainage Se loads to the SJR and the SLD. Flow and concentration data also have been compiled and graphed as determinants of load. Because collection of data suitable for more detailed projections is essential in the future, suggestions for monitoring also are given.

Discharge data from the Grassland Area (or historically the Drainage Problem Area) represent drainage from the source area (i.e., farmland sumps or agricultural drainage canals). Discharge was measured at the SLD outflow to Mud Slough (i.e., site B). Downstream sites from the SLD discharge are the combined discharge of Mud Slough and Salt Slough (MS and SS), the SJR at Crows Landing/Patterson below the confluence with the Merced River (CL/PATT, approximately 50 miles downstream from the farm agricultural discharge sumps), and the SJR at Vernalis (VERN, approximately 130 miles downstream from the agricultural discharge).

Time

Seasonal and inter-annual variability

The salt imbalance in the SJV is also a driving force for management activities. Selenium loads are compared to salt loads to elucidate the behavior of a conservative element, represented by salt (i.e., total dissolved solids or specific conductance as a surrogate for salt concentrations), to that of the non-conservative element, Se. Salt concentrations were calculated from specific conductance by using the equation:

specific conductance X 0.65 = mg/L total dissolved solids (TDS) or salt

A salt or total dissolved solid (TDS) load (in tons) is calculated using the equation:

[salt or TDS concentration (ppm) X volume of drainage (acre-feet)] X 0.00136 = salt or TDS load (tons),

where 0.00136 tons salt or TDS per acre-foot is equal to a concentration of one part per million (ppm) salt or TDS. Pounds can be converted to tons using the conversion factor: tons = lbs ÷ 2,000. Conversion factors used for salt and Se are compiled in Table 4.

Monthly, Daily and Hourly Measurements

The Grassland Bypass Channel Project (GBCP) Monitoring Plan provides for more frequent measurements of flow and Se and salt concentrations in the SLD (USBR et. al., 1996). The Grassland Area or Drainage Problem Area discharge was measured at the SLD outflow to Mud Slough (i.e., site B) for WY 1997 and 1998 (see also Appendix A, Table A7 and A8) (USBR et al., 1998 and 1999). Figures D1 through D8 show the variation for WY 1997 and WY 1998 in monthly SLD discharge (averages of daily flow measurements), monthly Se concentrations (averages of daily measurements), monthly salt concentrations [averages of daily specific conductance converted to TDS or salt concentration], and calculated monthly Se and salt loads. With initiation of the GBCP, drainage management is aimed at meeting monthly Se load targets listed in Appendix A, Tables A7 and A8 and shown in Appendix B, Figure B1**,** which are based on the seasonal nature of drainage generation. Maximum pre-irrigation occurs in February, maximum irrigation in July, and maximum discharge in February or March. Ranges of monthly variation for WY 1997 are: flow, 1,274 to 4,867 acre-feet; Se concentration 25 to 105 μg Se/L; salt concentration 2,175 to 3,255 mg/L, Se load 109 to 1,278 lbs, and salt load 4,325 to 20,091 tons. Ranges of monthly variation for WY 1998 are: flow, 1,403 to 7,094 acre-feet; Se concentration 43 to 105 μg Se/L; salt concentration 2,391 to 3,704 mg/L, Se load 178 to 1,598 lbs, and salt load 5,563 to 31,182 tons.

Figures D9 through D20 show the daily variation for WY 1997 and WY 1998 in SLD flow (based on 20-minute interval measurements), Se concentrations, TDS or salt concentrations (based on specific conductance measurements), Se loads, and salt loads (USBR et al., 1998 and 1999). Ranges of daily variation for WY 1997 are: flow 21 to 181 acre-feet; Se concentration 15 to 116 μg Se/L; and salt concentration 1,703 to 3,671 mg/L. Daily loads vary from 1.1 to 54 lbs Se and 66 to 860 tons salt. Ranges of daily variation for WY 1998 are: flow 20 to 288 acre-feet; Se concentration 20 to 128 μg Se/L; and salt concentration 4,114 to 2,230 mg/L. Daily loads vary from 2.7 to 69 lbs Se and 83 to 1,218 tons salt.

Figure D21 shows the hourly variation in Se concentration and conductivity for the SLD discharge for 6/26/97 (Rudy Schnagl, CCVRWQCB, personal communication, 6/1/98). Ranges of hourly variations are: Se concentration 47 to 78 μg Se/L; and conductivity 4,280 to 4,675 μmhos/cm (equivalent to 2,782 to 3,039 mg/L TDS).

Figures D22 and D23 compare monthly Se load and concentration data for the SJR at Crows Landing downstream of the SLD discharge for WY 1997 and 1998 (USBR et al., 1998 and 1999). In

WY 1997 Se concentrations were lower compared to those of WY 1998 because flow in the SJR below the Merced River in WY 1998 was sustained at a higher level for a longer period than WY 1997 due to increased snowmelt flowing in the Merced River. The competing seasonal effects of increased source load due to increased applied water and dilution afforded by the Merced River resulted in a Se load of 9,054 lbs for WY 1997 and 15,884 lbs for WY 1998, but only violation of the 5 µg Se/L objective in WY 1997, not in WY 1998 at the SJR below the Merced River. Figures D24 and D25 compare salt load and concentration data for the SJR at Crows Landing for WY 1997 and 1998. Salt load and concentration patterns generally follow those for Se load and concentration in WY 1997, but the salt concentration pattern deviates from that of Se concentration in WY 1998. Ranges of monthly variation for WY 1997 are: flow 28,761 to 1,212,948 acre-feet; Se concentration, 0.36 to 6.8 µg Se/L; salt concentration 109 to 952 mg/L; Se load, 149 to 1,533 lbs; and salt load, 24,563 to 242,735 tons. Ranges of monthly variation for WY 1998 are: flow 40,200 to 998,158 acre-feet; Se concentration, 0.69 to 2.6 µg Se/L; salt concentration 108 to 934 mg/L; Se load, 262 to 3,133 lbs; and salt load, 37,006 to 284,356 tons.

Daily measurements also were taken during WY 1997 and 1998 for the SJR at Crows Landing (USBR et al., 1998 and 1999). Figures D26 through D31 show the WY-1997 daily variation of flow, Se and salt concentrations, and calculated daily Se and salt loads. Ranges of daily variation for WY 1997 are: flow 413 to 37,100 cfs or 818 to 73,458 acre-feet; Se concentration 0.1 to 9.7 µg Se/L; salt concentration 82 to 1,165 mg/L; Se load 1.3 to 183 lbs; and salt load 500 to 15,956 tons. Figures D32 through D37 show the WY1998 daily variation of flow, Se and salt concentrations, and calculated daily Se and salt loads. Ranges of daily variation for WY 1998 are: flow 483 to 24,200 cfs or 956 to 47,916 acre-feet; Se concentration 0.5 to 4.1 µg Se/L; salt concentration 79 to 1,165 mg/L; Se load 3.4 to 183 lbs; and salt load 809 to 15,482 tons.

Space

Given in Tables D1 and D2 for WY 1986 to 1997 are the percentages of the input Se (non-conservative element) and salt (conservative element) loads to the discharged load of Se and salt for the SJR at Vernalis, the entrance to the Bay-Delta (CCVRWQCB, 1996a; b; 1998d; e; f; g; h). These data show that 162% to 72% of the Se load to the SJR is discharged above or at the Merced River inflow to the SJR which would include the loads from both slough and river sources (i.e., the SJR is the only outlet from the SJV). The Merced River inflow to the SJR is approximately 60 miles above Vernalis, which is the entrance of the SJR to the Bay-Delta. Between the Merced River confluence and Vernalis, the Tuolumne and Stanislaus Rivers flow into the SJR. Approximately 68% to 87% of the salt load to the SJR is discharged above or at the Merced River inflow to the SJR. Figure D38 shows the percent of the Se load from the Drainage Problem Area, combined Mud and Salt Sloughs, and Crows Landing/Patterson normalized to the Se load at the SJR at Vernalis. Figure D39 shows the percent of the salt load from the Drainage Problem Area, combined Mud and Salt Sloughs, and Crows Landing/Patterson normalized to the salt load at the SJR at Vernalis. The pattern of Se's non-conservative behavior is different from that of the conservative salt. The Se loads measured as the input to the system (i.e., primary drainage canals, Drainage Problem Area) are perpetually different from those measured as the outputs from the system (i.e., downstream in wetland sloughs or the SJR). Downstream Se loads show both decreases (measured at Salt and Mud Sloughs) and increases (SJR at Crows Landing and Vernalis) (see Appendix B, Tables B4 to B7). In the absence of the SLD extension to the Bay-Delta, which would provide a single source of Se at a single discharge point, loads discharged from the SJR at Vernalis to the Delta are not likely to equal loads discharged into the river from the drainage source area.

Selenium is persistently discharged from the Grassland area to the SJR, but is dependent on the monitoring site location within the Grassland area (Table 5; Appendix B, Tables B4 to B7; Appendix A, Figures A9 and A10). The upstream discharge represents managed components of flow and load. Data in these graphs for WY 1986 to WY 1998 generally can be related to physical variables that affected drainage conditions (e.g., drought 1987 through 1992, California Coast Range flooding in 1995, and Sierra Nevada flooding in 1997; also see Appendix A, Figure A10, SJV annual rainfall for CIMIS #124). Ranges of yearly variation for WY 1986 to 1997 for the DPA are: flow, 24,533 to 67,006 acre-feet; Se concentration 52 to 80 μg Se/L; Se load 5,083 to 10,959 lbs. Ranges of yearly variation are for Mud and Salt Sloughs are: flow, 85,428 to 288,253 acre-feet; Se concentration 10 to 16 μg Se/L; Se load 2,919 to 10,694 lbs. Combining the data for Mud and Salt sloughs dampens the variation seen in each slough when influenced by agricultural discharge. Ranges of yearly variation for Crows Landing/Patterson are: flow, 0.29 to 4.18 million acre-feet/year; Se concentration 1 to 6.3 μg Se/L; and Se load 3,064 to 14,291 lbs/year. Ranges of yearly variation for Vernalis are: flow, 0.66 to 6.77 million acre-feet/year; Se concentration 0.6 to 3.0 μg Se/L; and Se load 3,611 to 17,238 lbs/year.

Except for WY 1990, data from 1986 to 1995 showed Se input loads (upstream drainage canals, Drainage Problem Area**,** Appendix B, Table B4) higher than output loads (downstream of Mud and Salt Sloughs, Appendix B, Table B5). Comprehensive monitoring data are not available to determine the Se "loss" (i.e., that amount of load unaccounted for) after transit through the Grasslands wetlands (estimated annual maximum potential attenuation of 50%).

Loads further downstream in the SJR at Patterson/Crows (Table 5; Appendix B, Table B6) and Vernalis (Table 5; Appendix B, Table B7) show increases over loads measured at Mud and Salt Sloughs, and in some cases, over loads measured furthest upstream (i.e., Drainage Problem Area). The increases may be due to other sources of Se entering the SJR or errors introduced through limitations of the data as noted above. During WY 1986 to WY 1998, the loads in the SJR at Patterson/Crows range from 3,064 to 15,884 lbs Se with the maximum occurring in WY 1998 (Appendix B, Table B6). The Se loads for the SJR at Vernalis from WY 1986 to WY 1997 range from 3,558 to 17,238 lbs, with the two highest values occurring in 1986 and 1995 (Appendix B, Table B7). In the referenced data, two values have been calculated for the SJR at Crows Landing for WY 1998 (15,501 lbs and 13,445 lbs) depending on sets of flow data. For WY 1998 for the SJR at Vernalis, the reported value is 15,810 lbs Se/year which is less than or similar to the value measured for the SJR at Crows Landing. A state prohibition limitation for drainage over 8,000 lbs Se from the Grassland Area was enacted in 1996.

Prediction of Short-Term Selenium Reservoirs

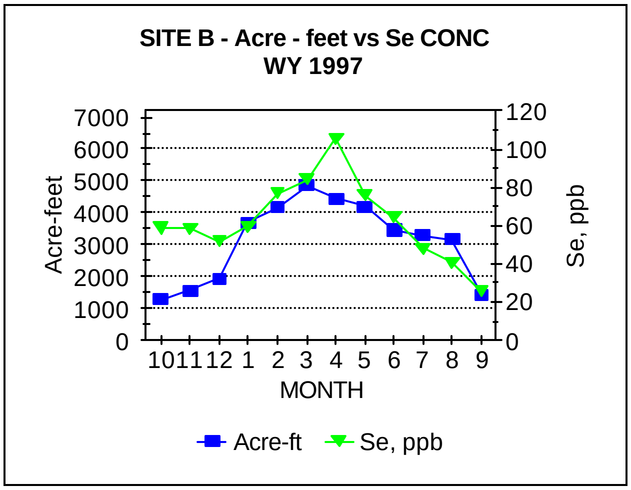
Data from WY 1986 to 1994 from the Grassland Area (or generically, the drainage source area) are given as an example of a managed agricultural drainage discharge system (CCVRWQCB, 1996a;b; 1998d; e; f; g; h; GAF, 1998b). Measurements for the drainage problem area are referred to agricultural drainage canals for WY 1986 to 1996 and site B (SLD discharge into Mud Slough) for WY 1997 and WY 1998. Figures D40 through D44 show, using data from WY 1986 to 1997, general relations among annualized amounts of:

- irrigation water applied to the drainage source area;
- the flow generated from the drainage source area (i.e., discharge);
- the concentration of Se in the generated discharge; and
- the loads of salt and Se generated from the drainage source area.

This series of figures show some of the variables that affect load generation, but not the fundamental processes controlling the distribution and transport of Se and salt. Based on annualized data, Figure D40 shows that as total water (applied irrigation water plus precipitation) increases, flow from the Drainage Problem Area increases. Figure D41 shows that as total applied water increases, Se and salt concentrations in the discharge decreases. Figure D42 shows that as total applied water increases, Se and salt loads from the Drainage Problem Area increase. Figure D43 shows that as flow from the Drainage Problem Area increases, Se and salt concentrations decreases. Figure D44 shows that as flow from the Drainage Problem Area increases, Se load increases.

Based on monthly and daily data these annual relations are not valid**.** Figures D45 and D46 show the relation among flow, concentration, and load using daily measurements for WY 1997 and 1998 at the SLD discharge to Mud Slough (site B) (USBR et al., 1998; 1999). In WY 1997 Se load and concentration increase with flow. In WY 1998 however, concentration and load decrease at flows greater than approximately 100 cubic feet per second, thus showing some drainage relief through dilution at the higher flows during storms in February 1998. These data have been generalized in Figure 6 to help denote the characteristics of source water versus receiving water.

Figures D47 through D56 are a series of graphs that depict the relation between load, concentration, applied water, and flow or discharge at site B in the SLD on a monthly basis for the Grassland Area. Figures D47 through D50 are WY-1997 and -1998 summaries using monthly averages of flow (i.e., discharge), Se load, and Se concentration along with amounts of applied water (irrigation and precipitation). Figures D51 and D52 show a monthly average of WY 1986 through 1994 (the base year average used for generating the GBCP load targets, see Appendix B, Figure B1) for the same parameters. For comparison, Figures D53 through D56 are summaries of salt load and salt concentration data for the SLD discharge shown in a similar series of graphs for that of Se discharge in WY 1997 and 1998. Patterns of loading to the SLD are similar through the series of graphs, showing peak Se loads and concentrations during the months of March or April. Maximum application of water occurred in June, July, and August. Winter rainfall peaks can be seen especially in WY 1998 during February.



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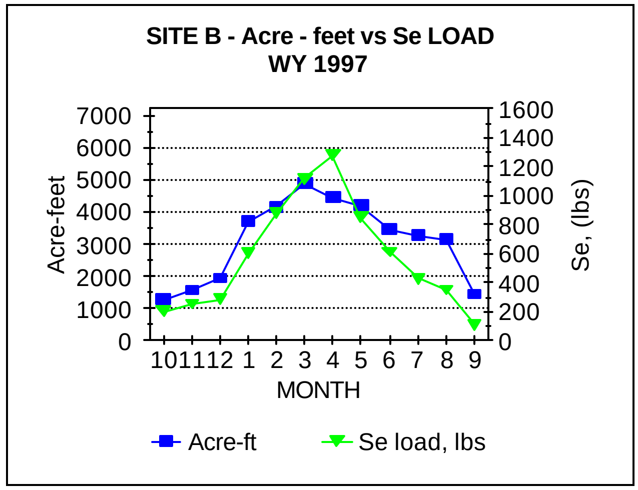

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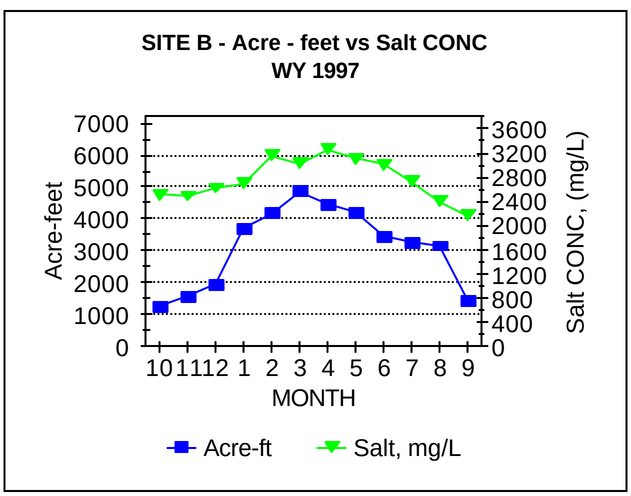

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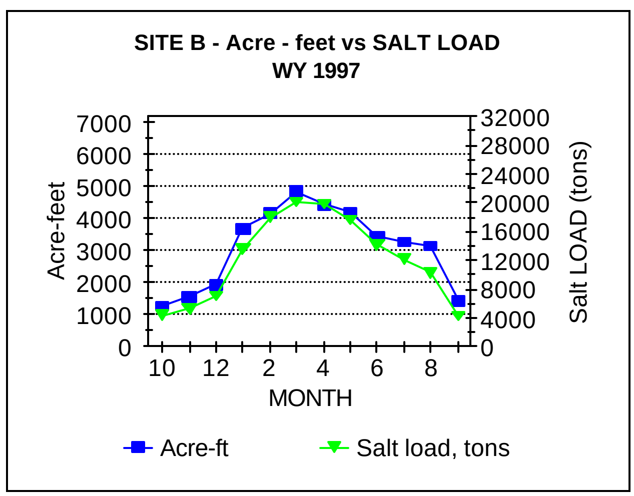

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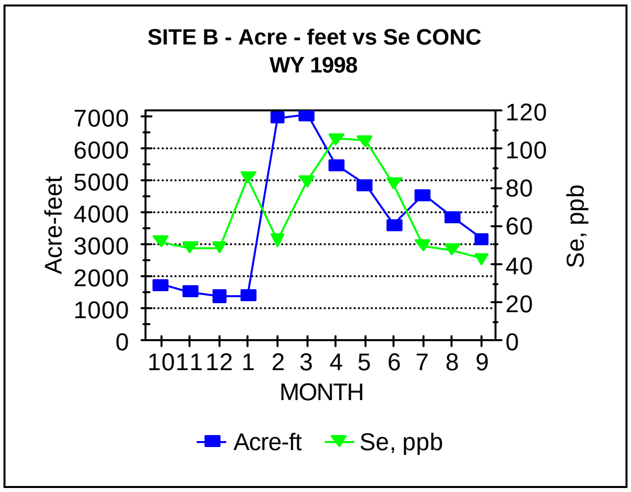

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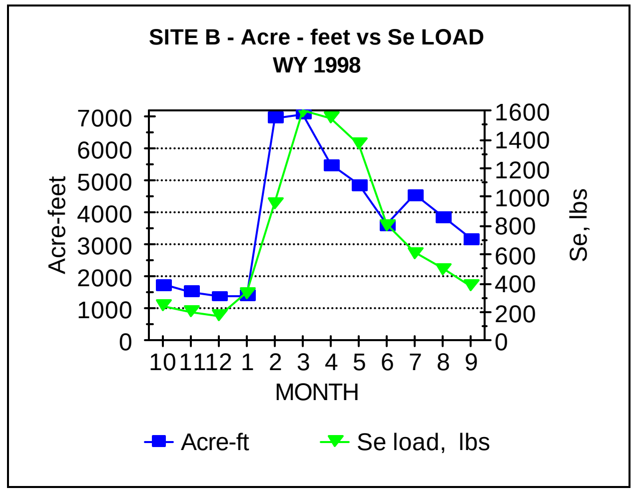

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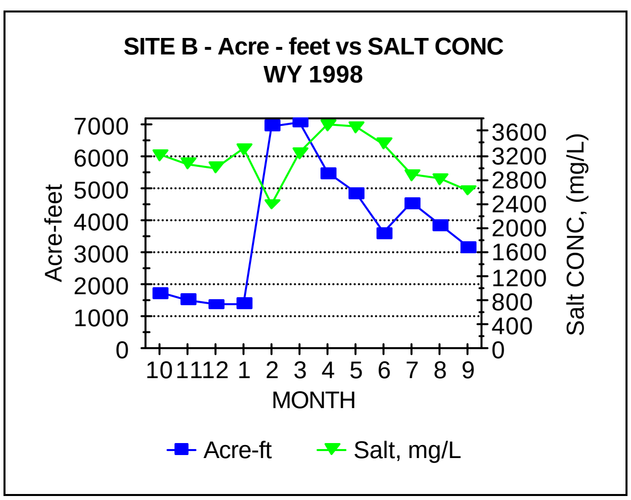

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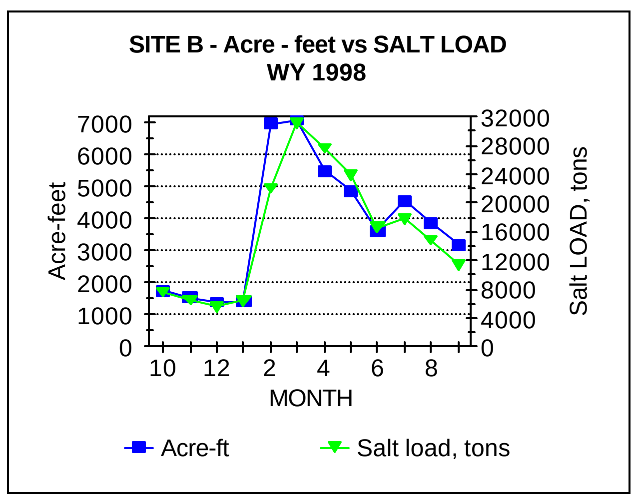

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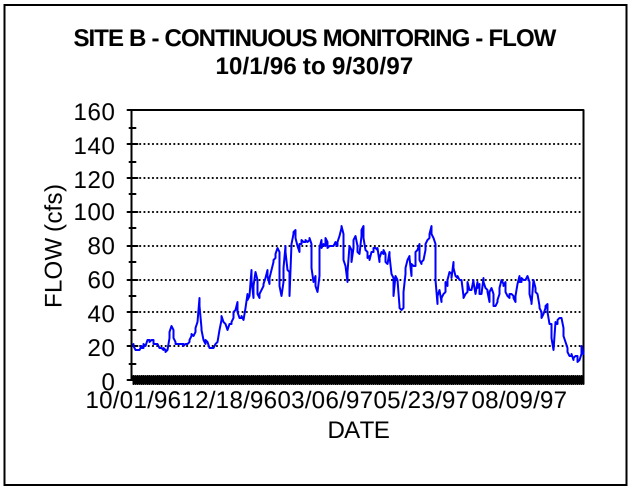

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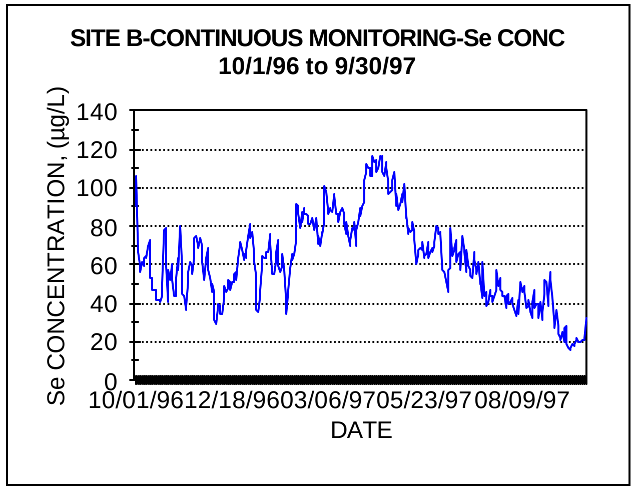

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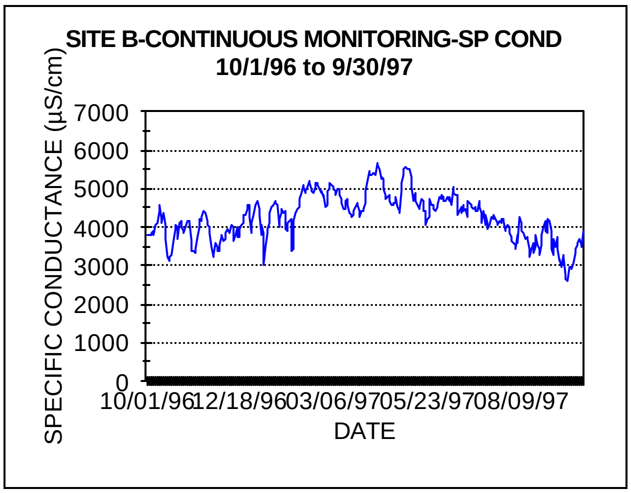

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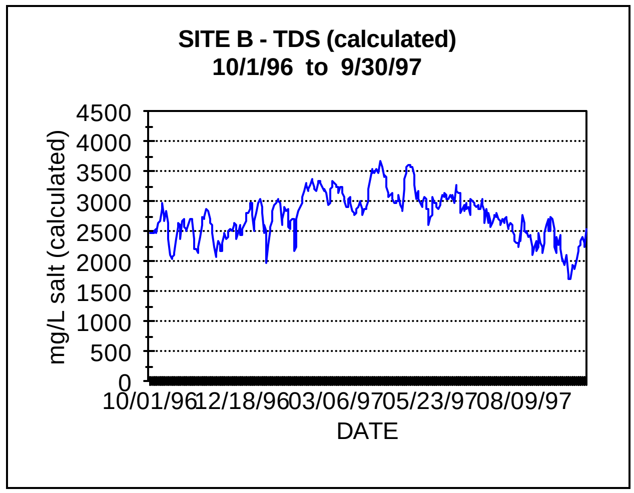

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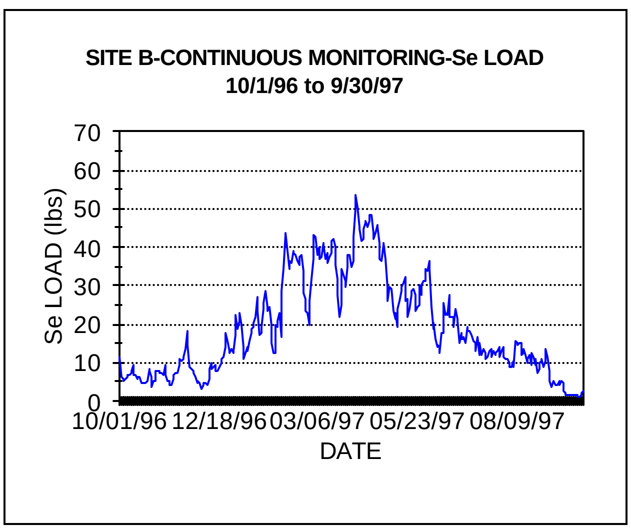

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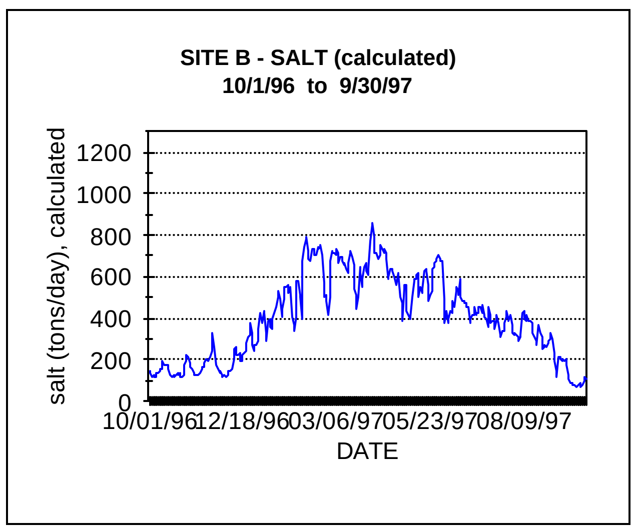

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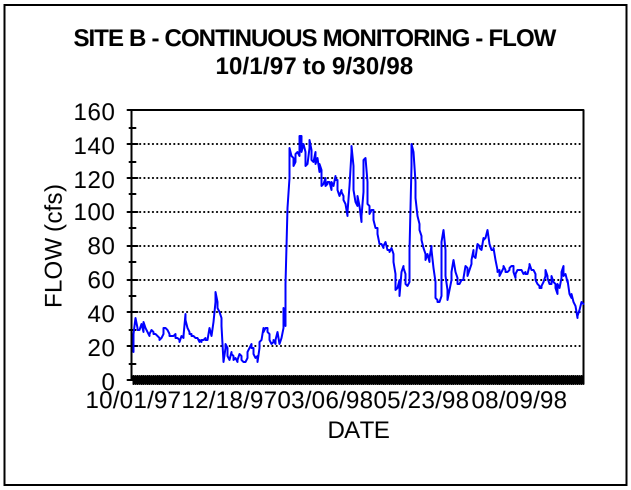

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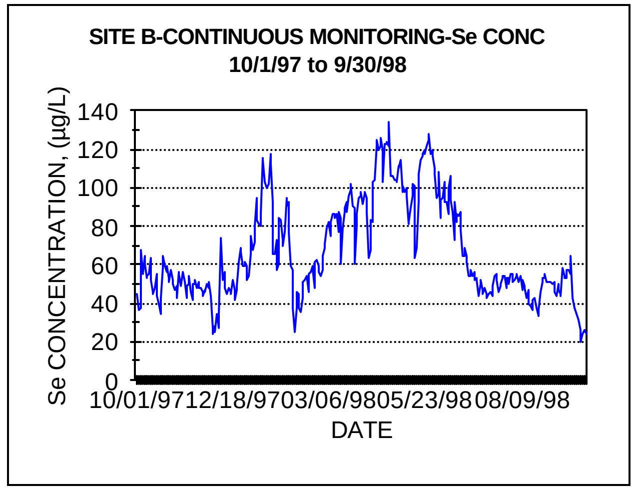

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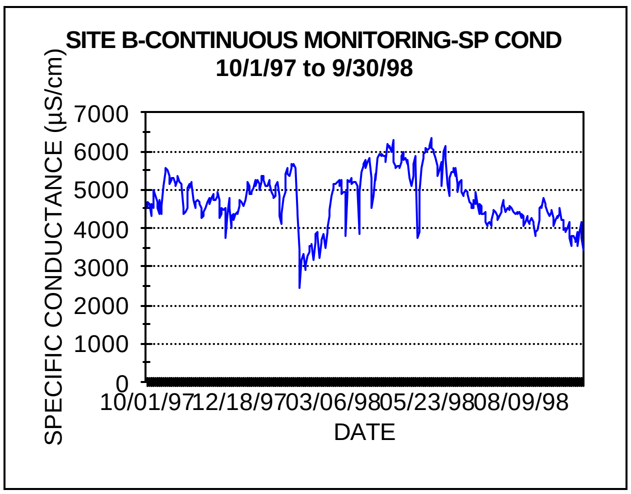

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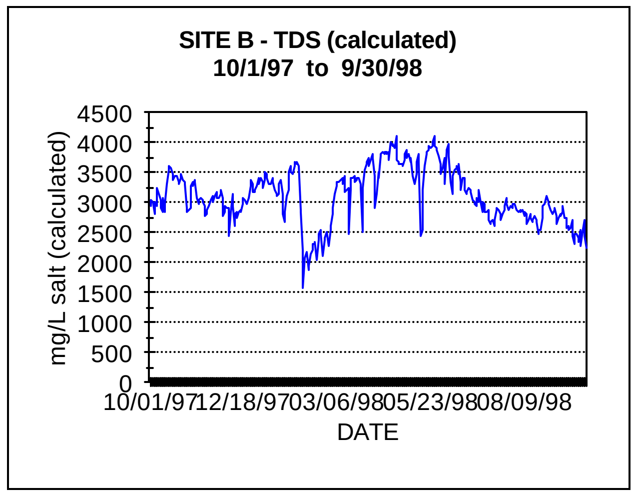

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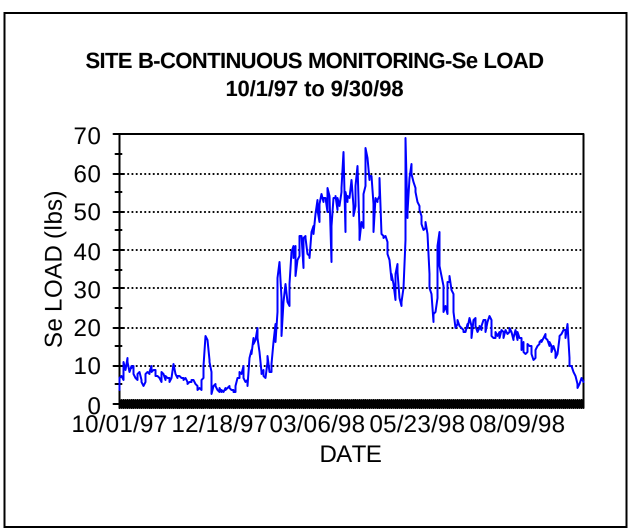

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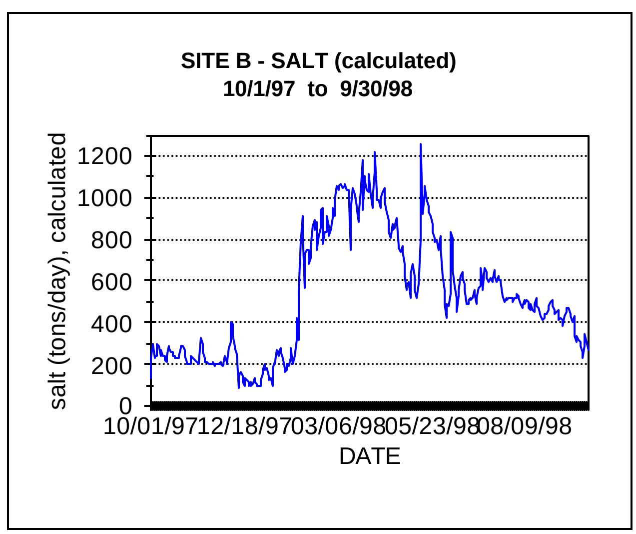

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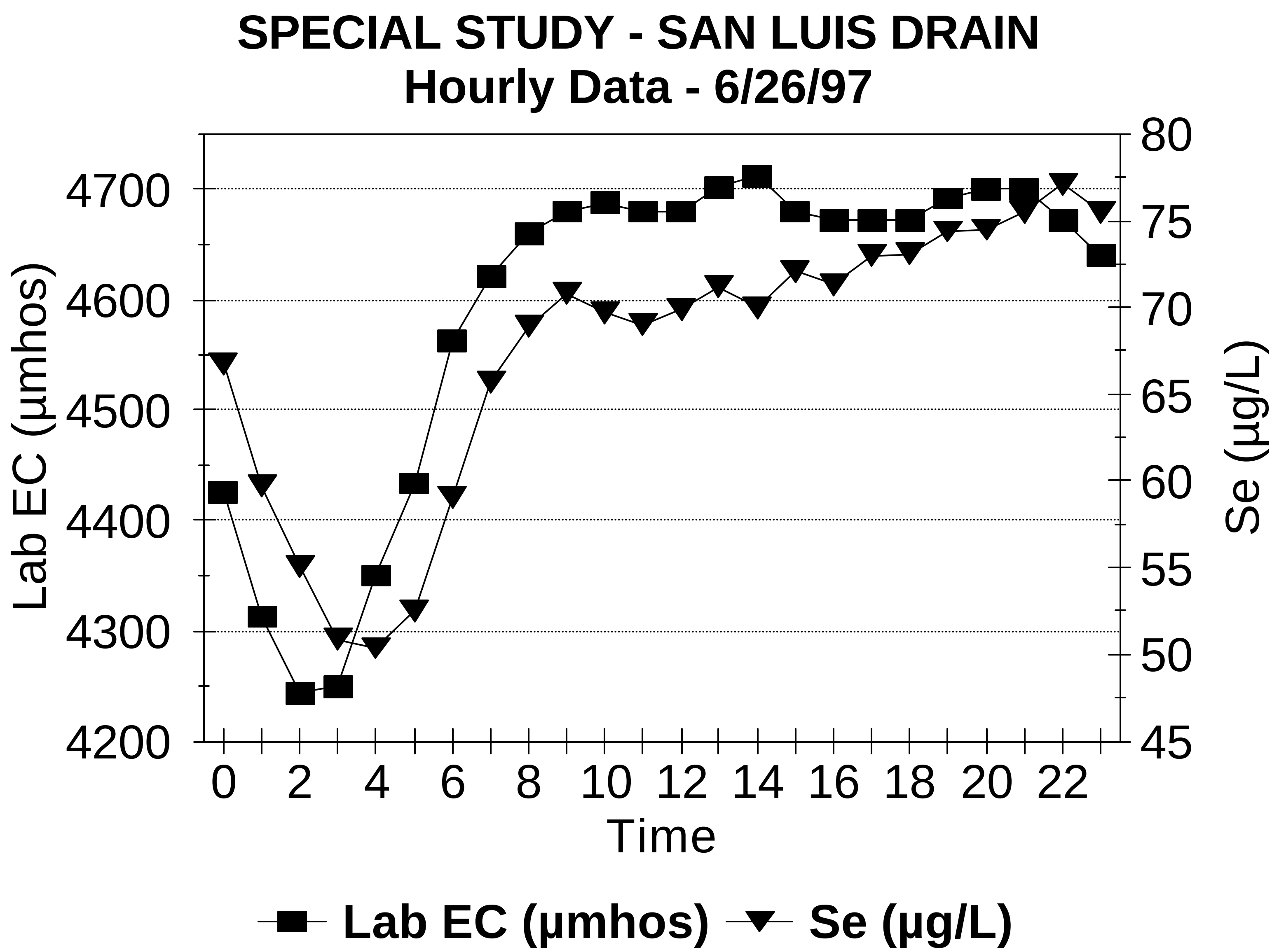
SPECIAL STUDY - SAN LUIS DRAIN
Hourly Data - 6/26/97
Lab EC (µmhos)
Se (µg/L)
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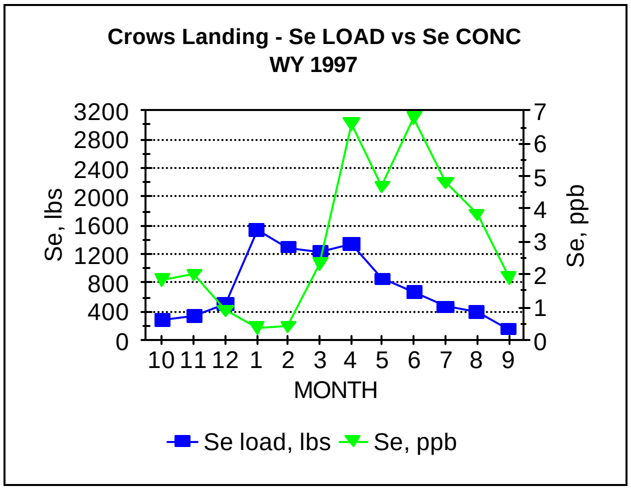
4300
4400
4500
4600
4700
45
50
55
60
65
70
75
80
0
2
4
6
8
10
12
14
16
18
20
22
Time
Lab EC (µmhos)
Se (µg/L)

Figure D21



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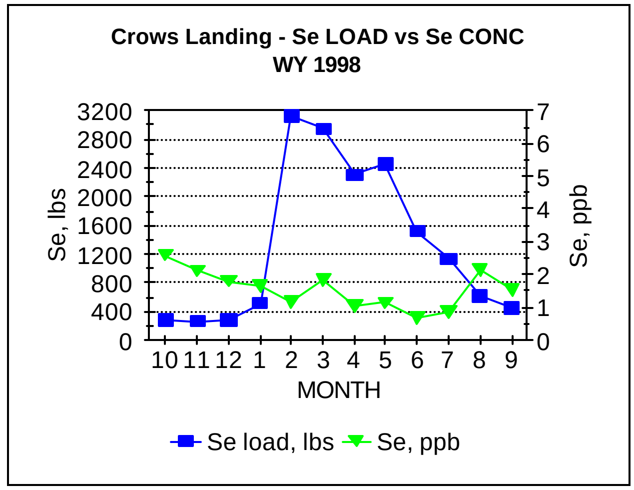

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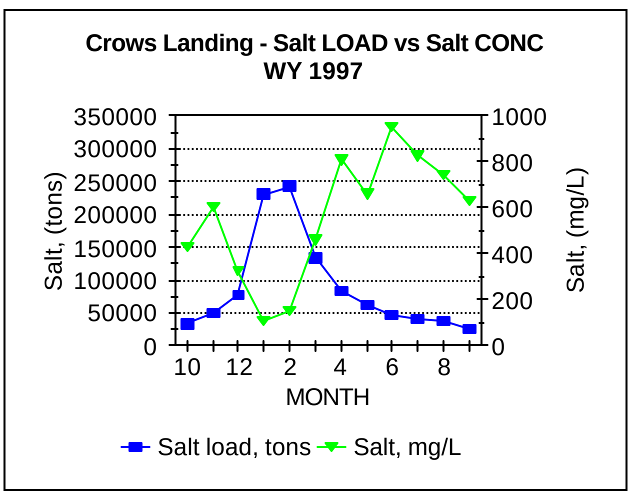

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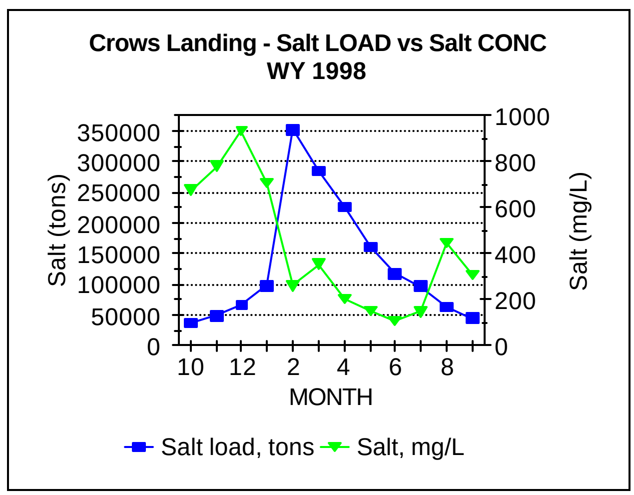

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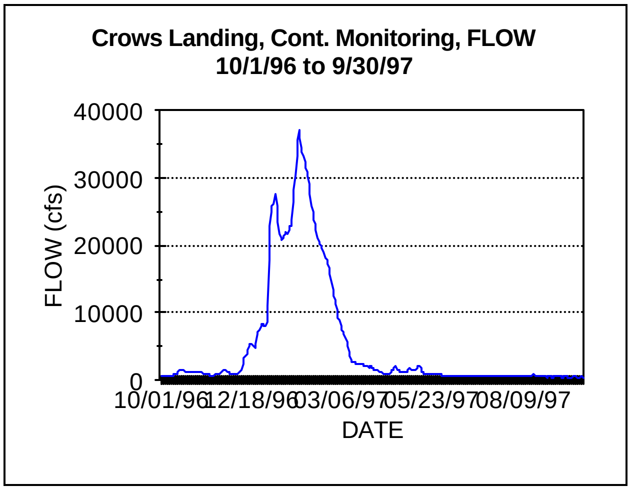

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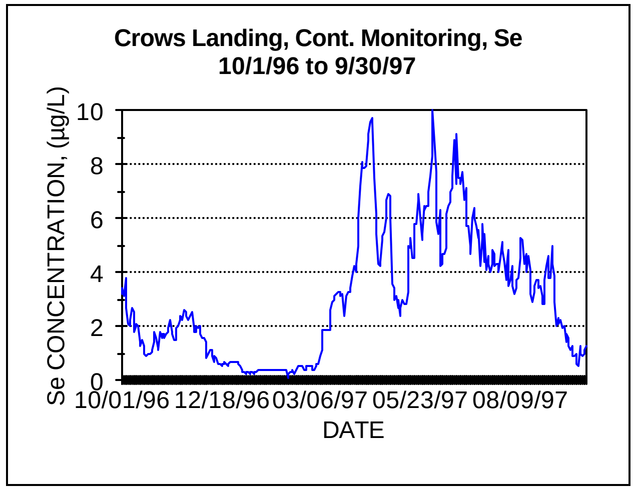

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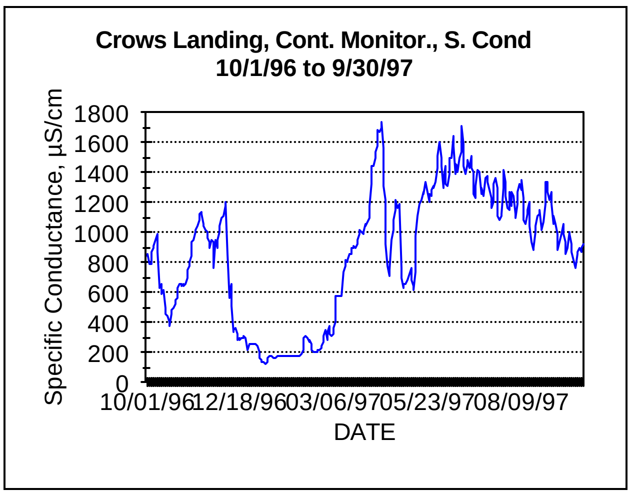

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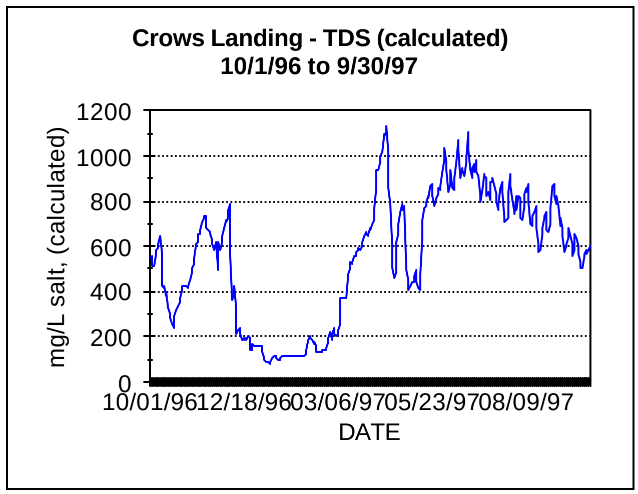

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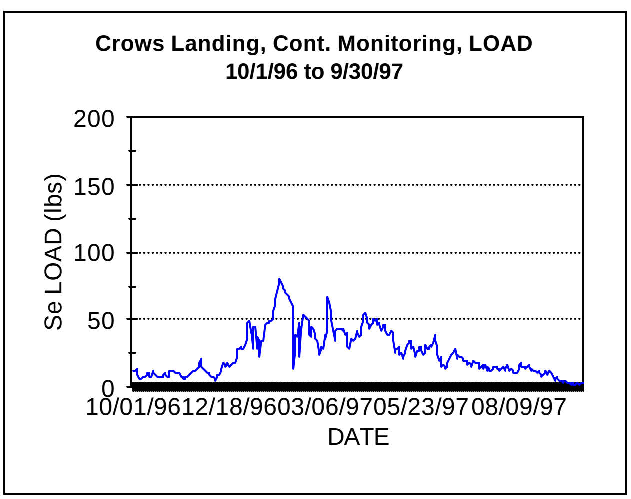

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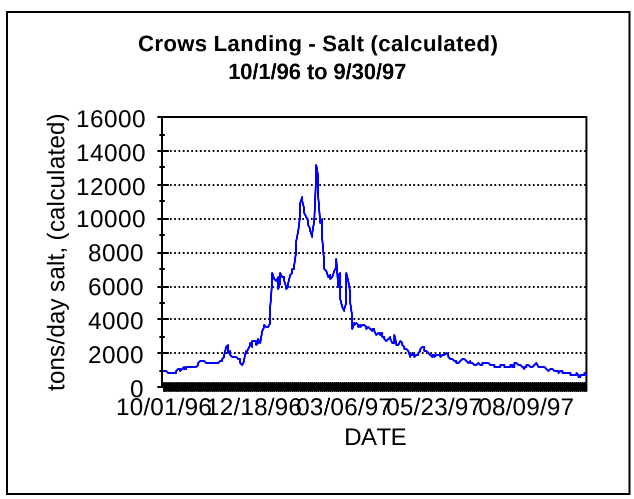

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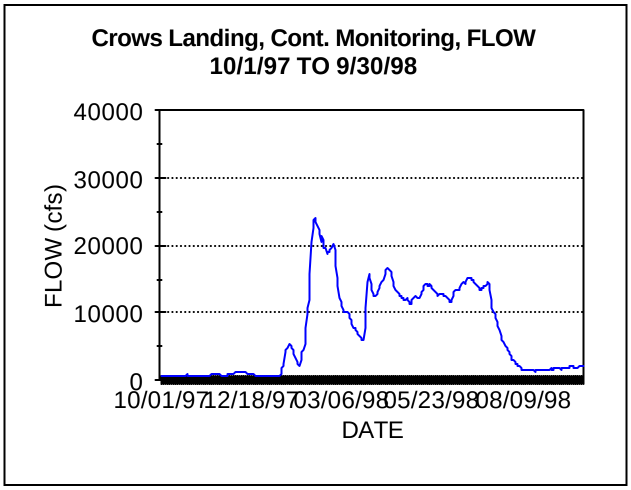

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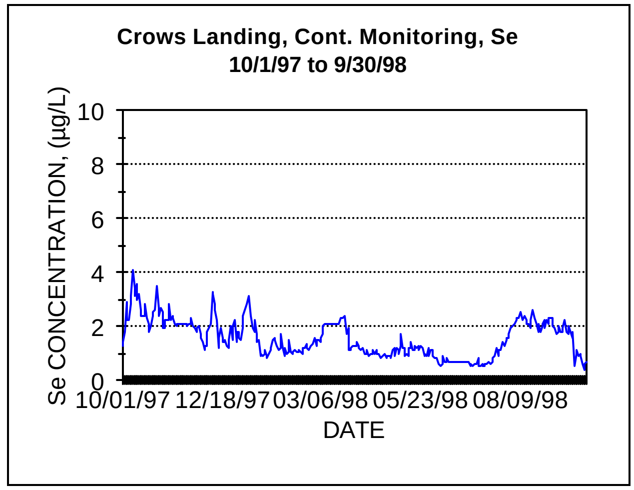

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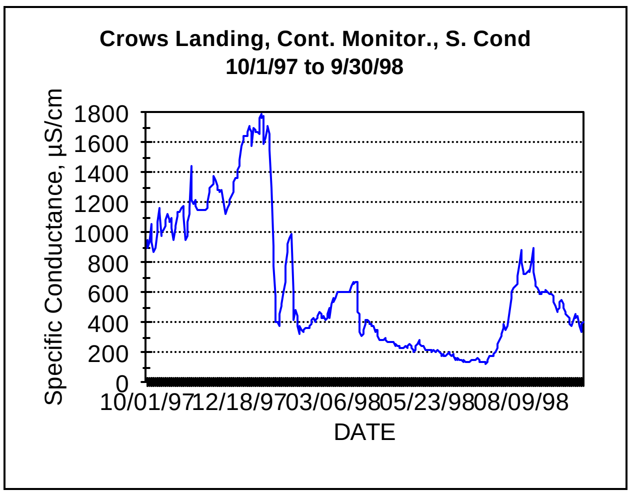

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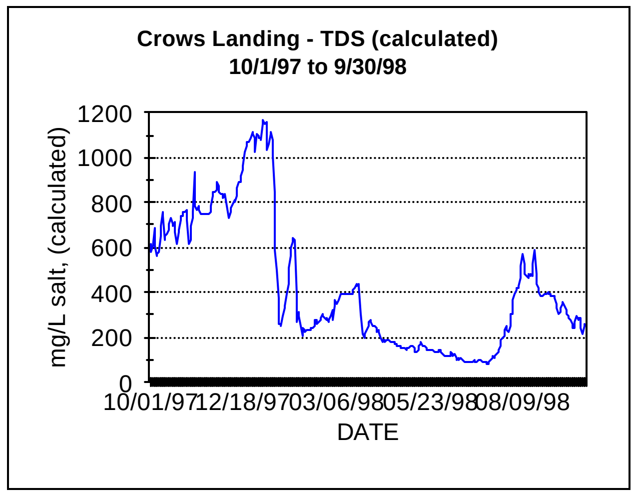

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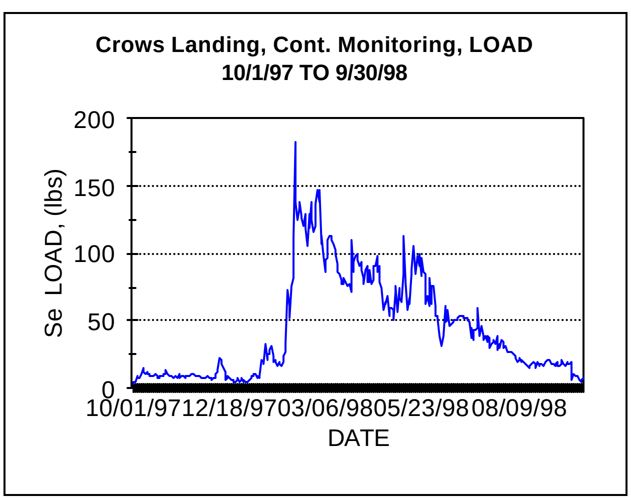

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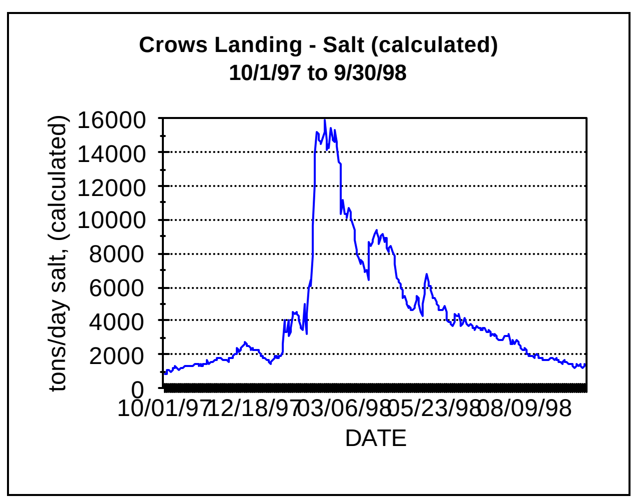

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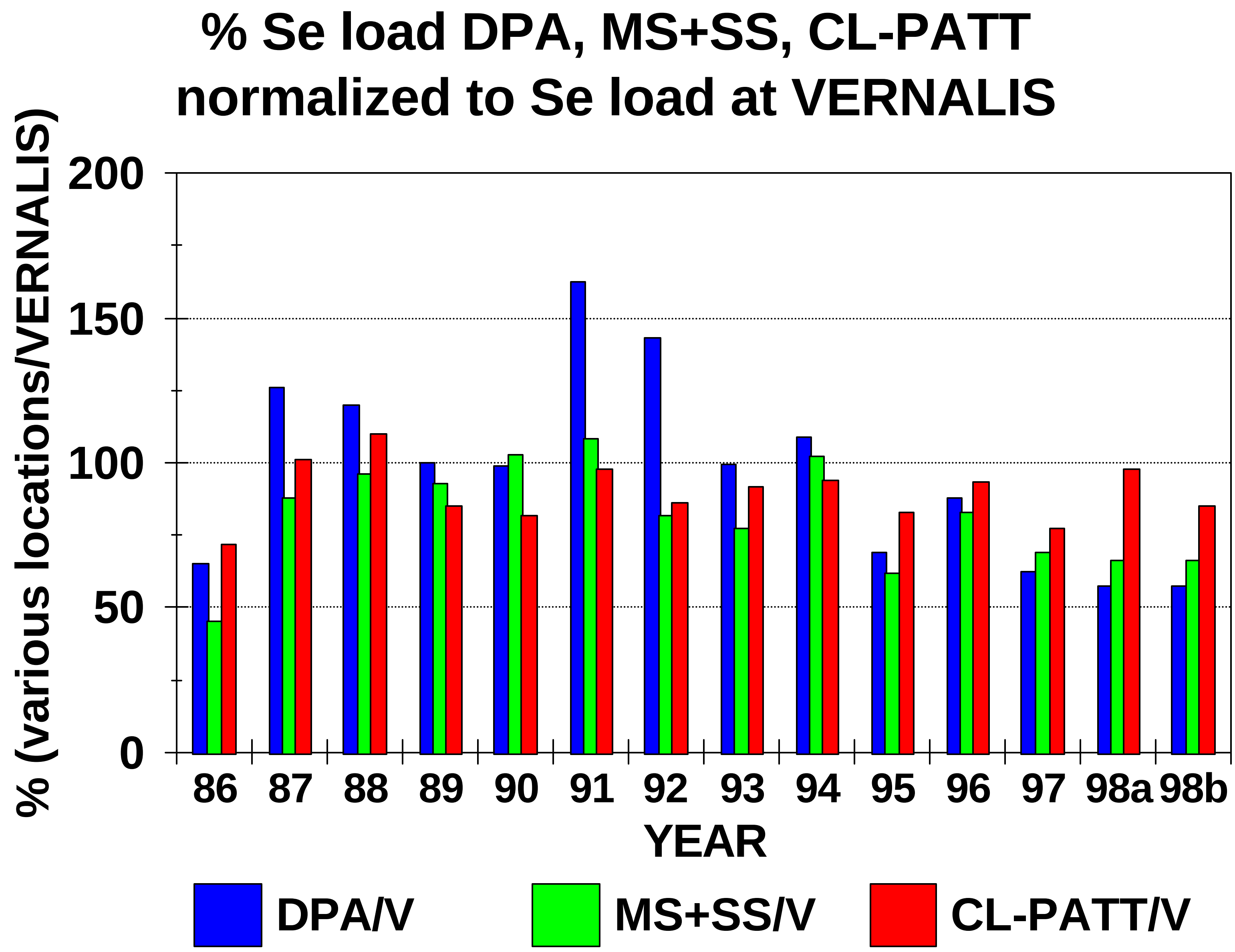


% Se load DPA, MS+SS, CL-PATT
normalized to Se load at VERNALIS
% (various locations/VERNALIS)
200
150
100
50
0
86
87
88
89
90
91
92
93
94
95
96
97
98a
98b
YEAR
DPA/V
MS+SS/V
CL-PATT/V

FigureD38

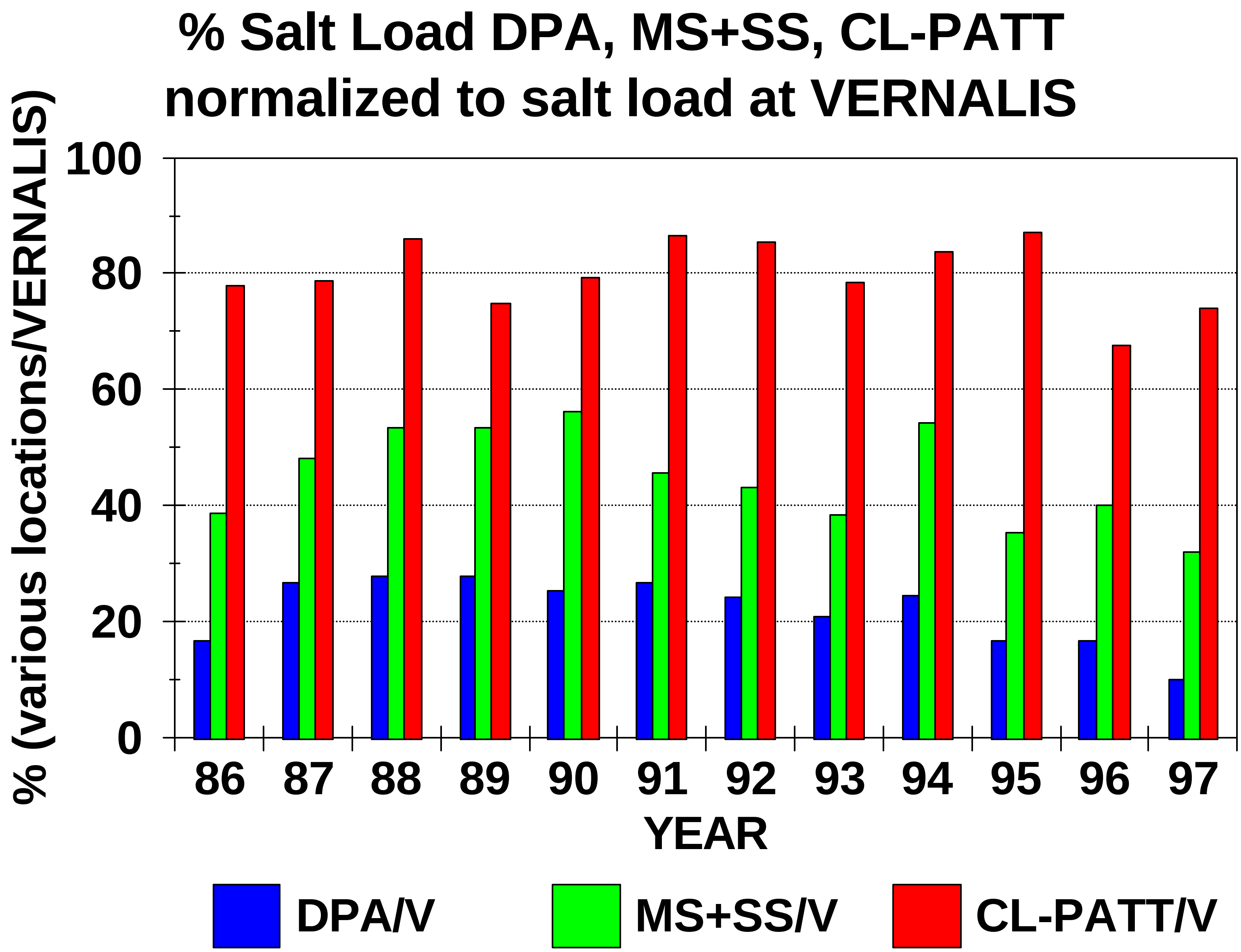

% Salt Load DPA, MS+SS, CL-PATT
normalized to salt load at VERNALIS
% (various locations/VERNALIS)
100
80
60
40
20
0
86
87
88
89
90
91
92
93
94
95
96
97
YEAR
DPA/V
MS+SS/V
CL-PATT/V

Figure D39

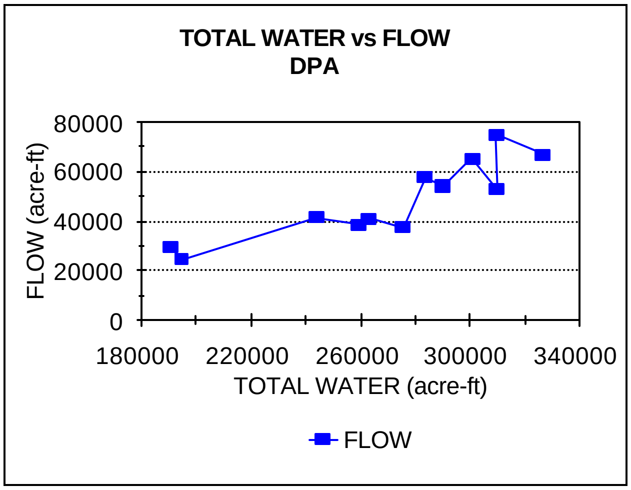


Figure D40

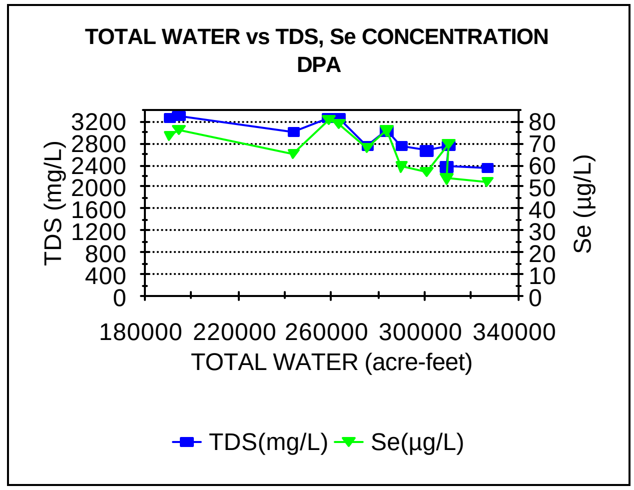


Figure D41

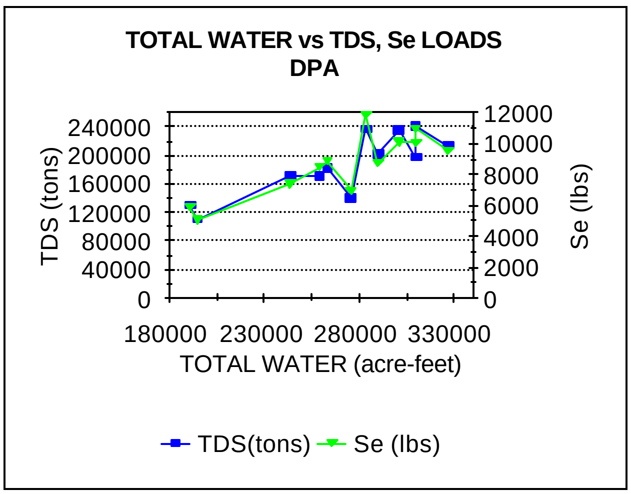


Figure D42

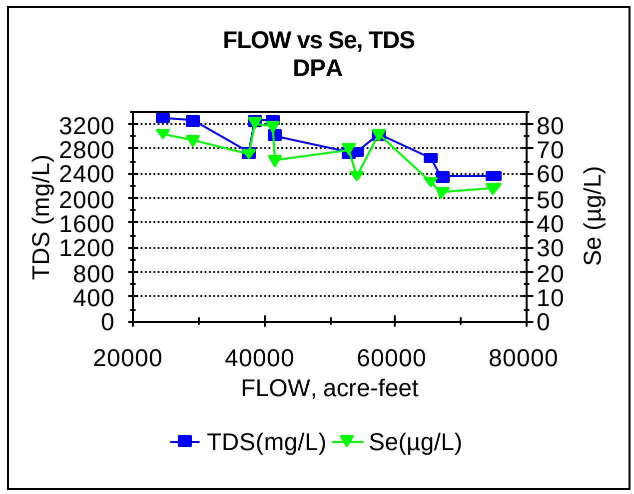


Figure D43

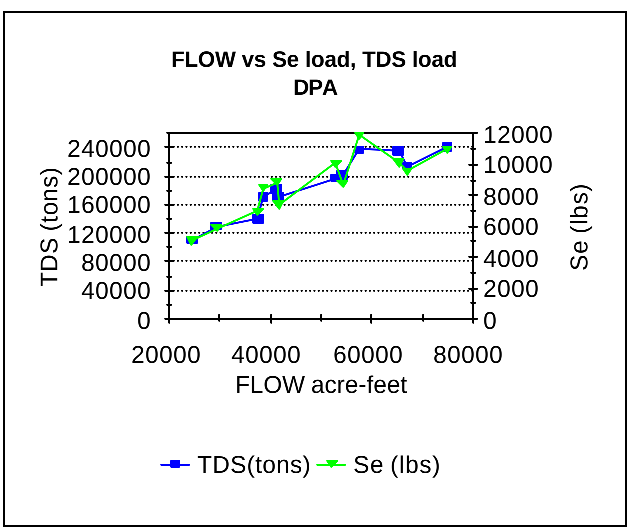
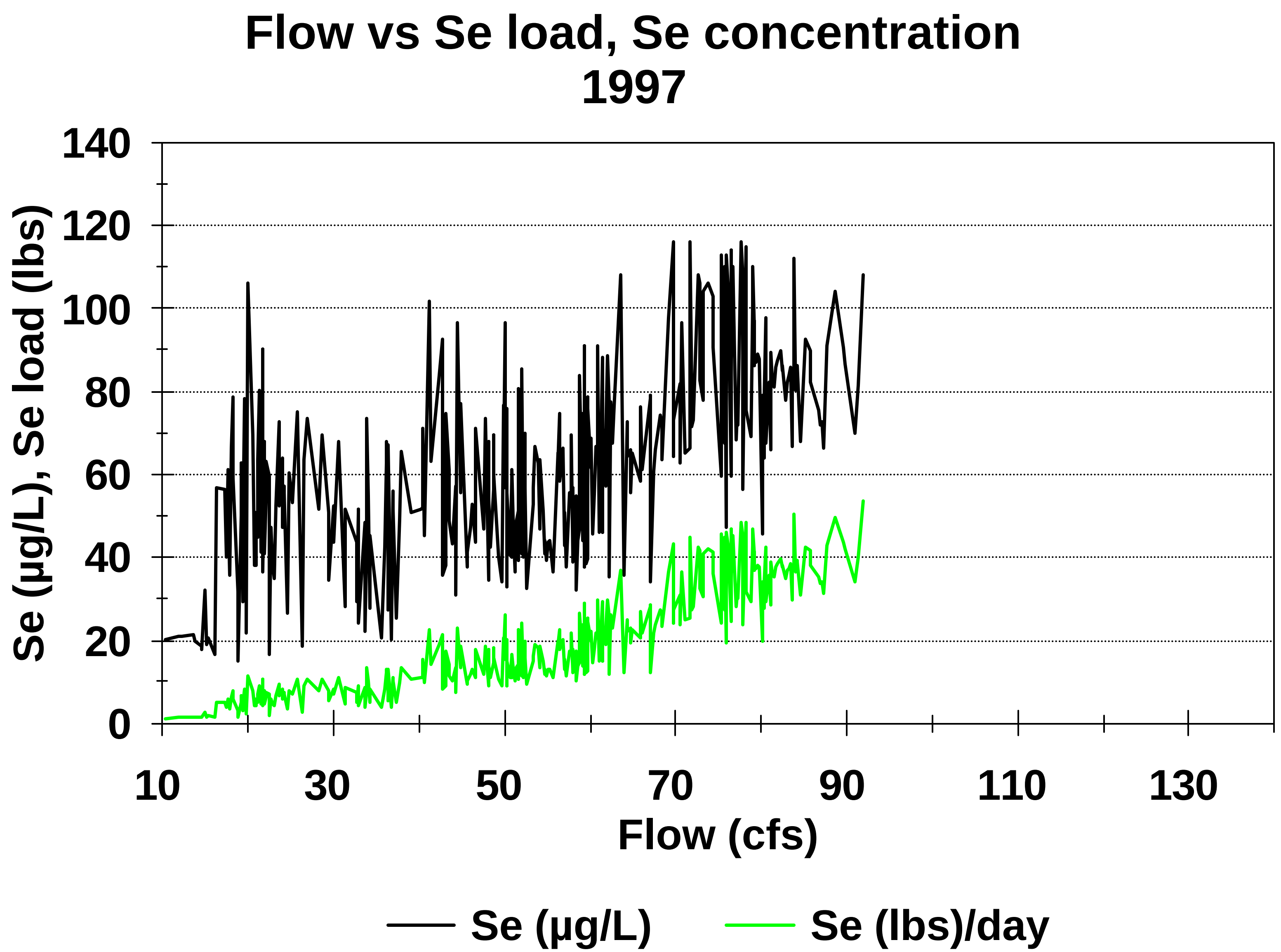
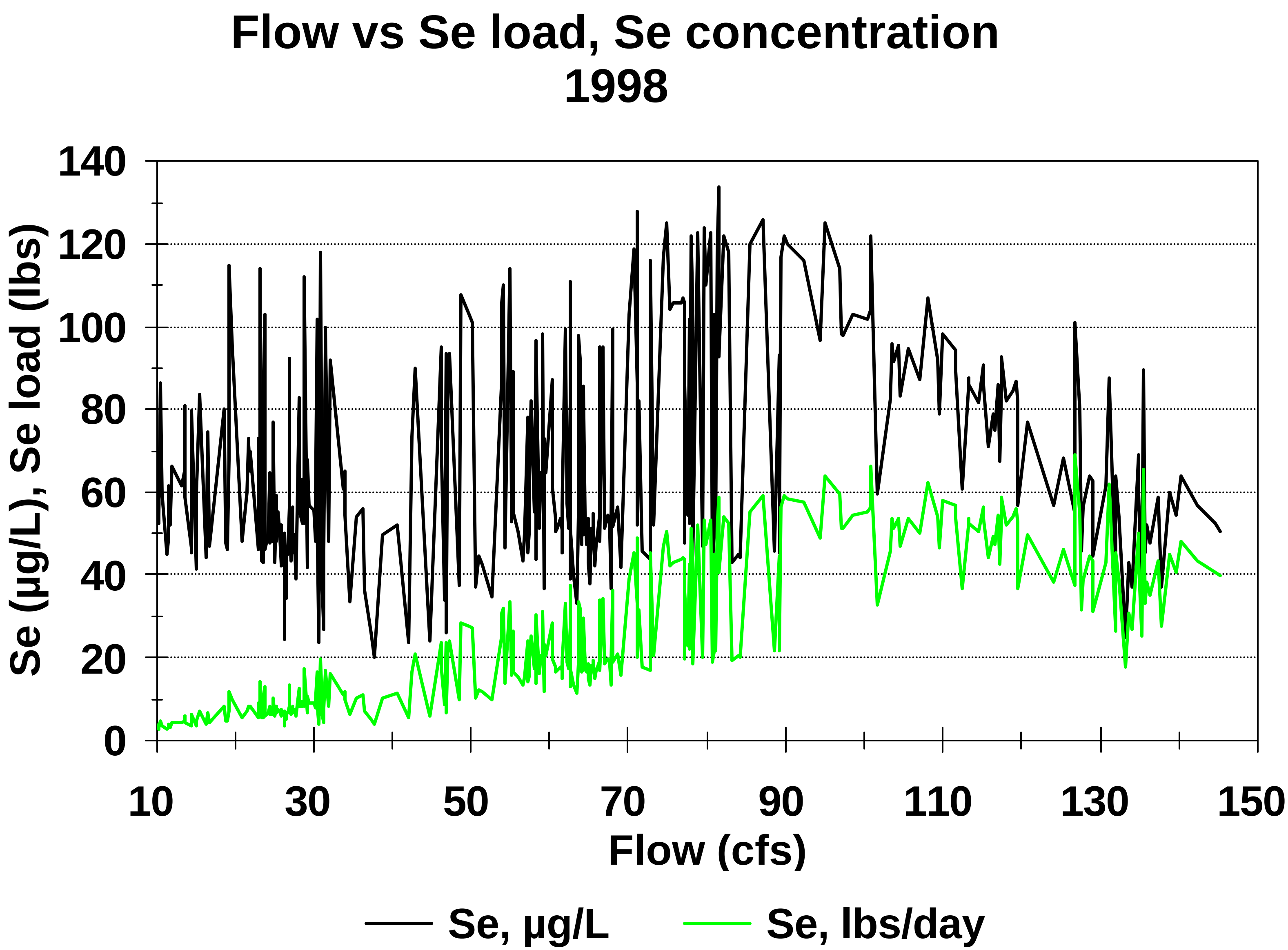


Figure D44



Flow vs Se load, Se concentration
1997
140
120
100
80
60
40
20
0
Se (µg/L), Se load (lbs)
10
30
50
70
90
110
130
Flow (cfs)
Se (µg/L)
Se (lbs)/day

Figure D45



Flow vs Se load, Se concentration
1998
Se (µg/L), Se load (lbs)
140
120
100
80
60
40
20
0
10
30
50
70
90
110
130
150
Flow (cfs)
Se, µg/L
Se, lbs/day

Figure D46

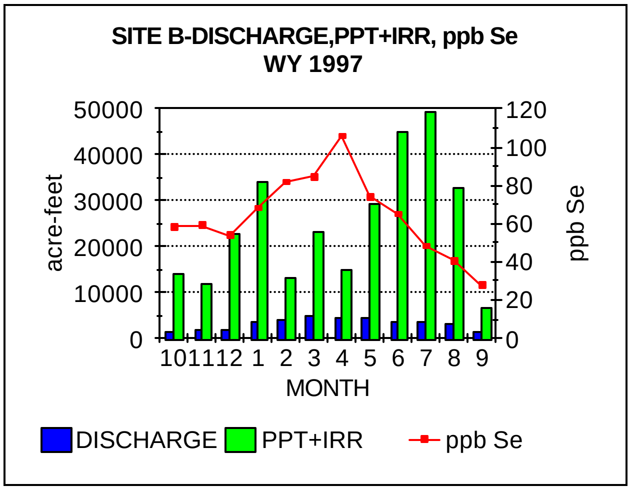


Figure D47

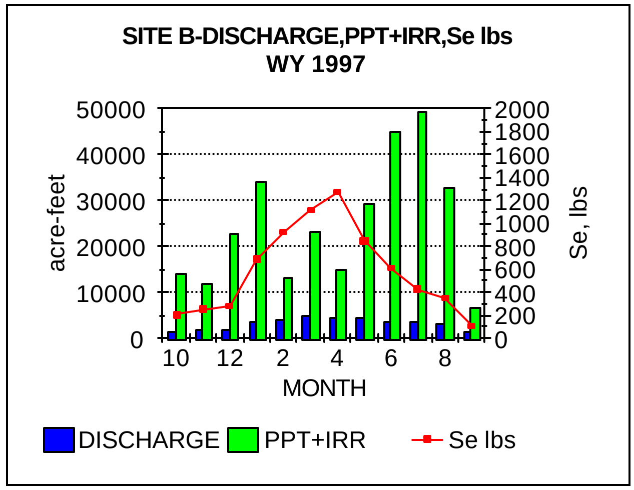


Figure D48

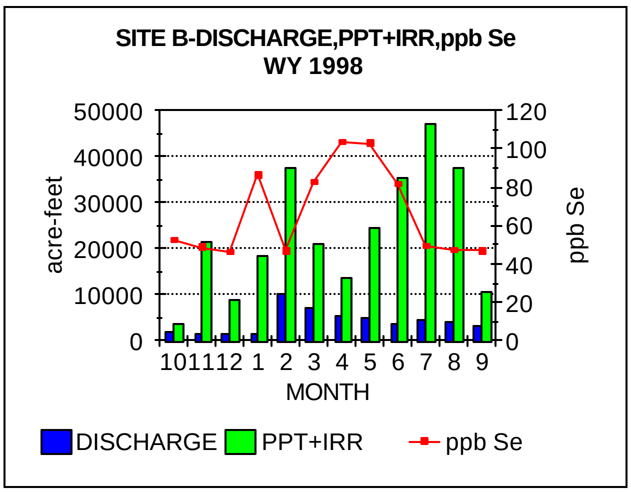


Figure D49

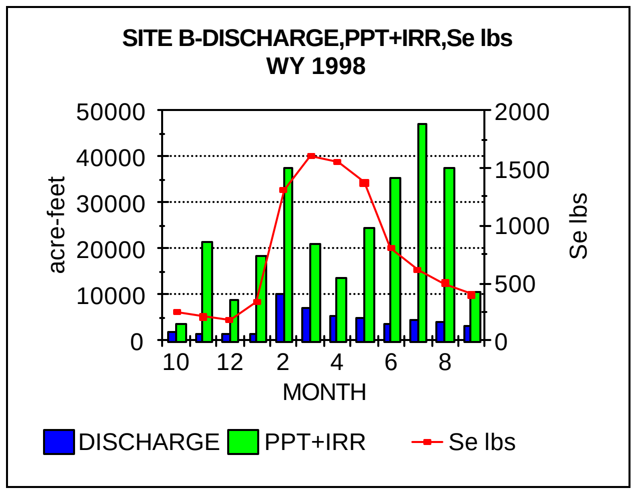


Figure D50

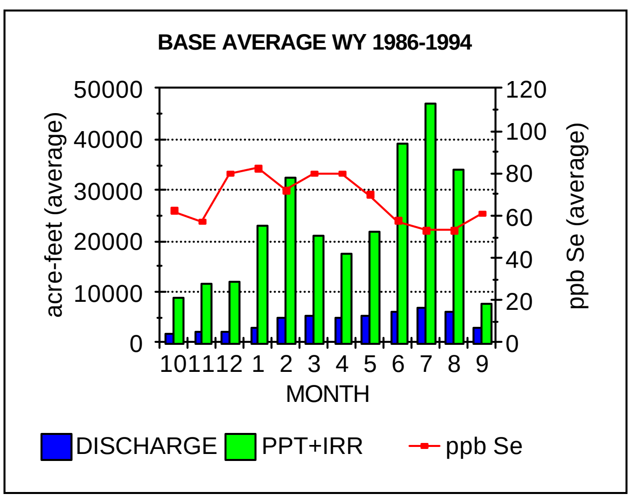


Figure D51

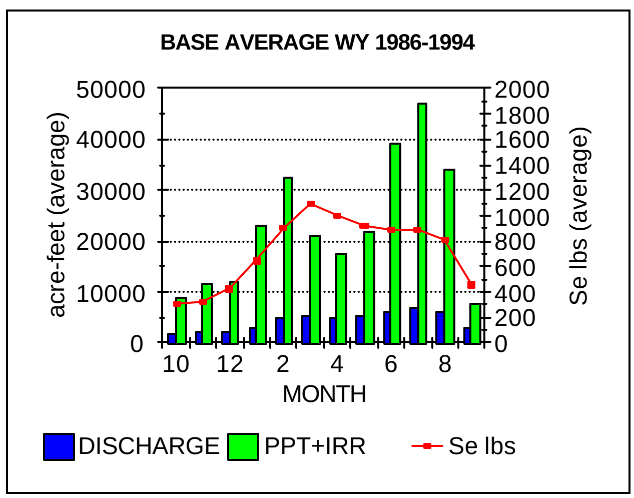


Figure D52

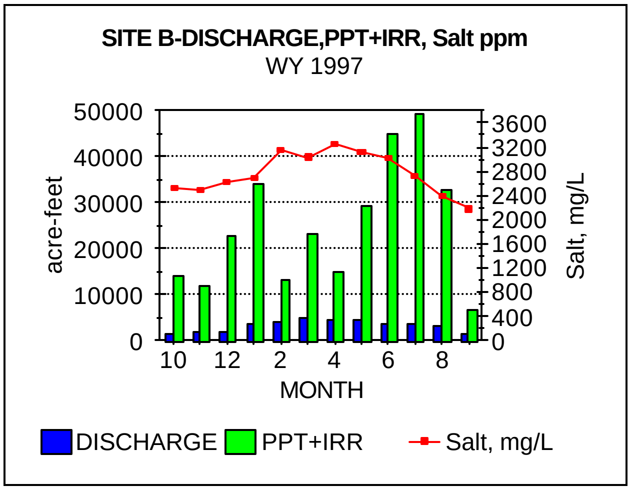


Figure D53

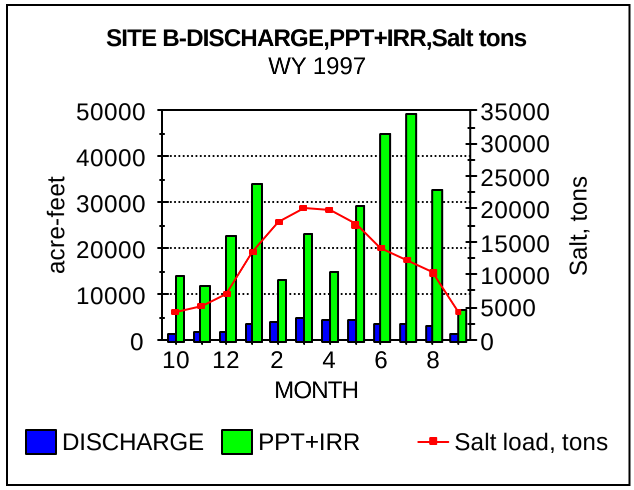


Figure D54

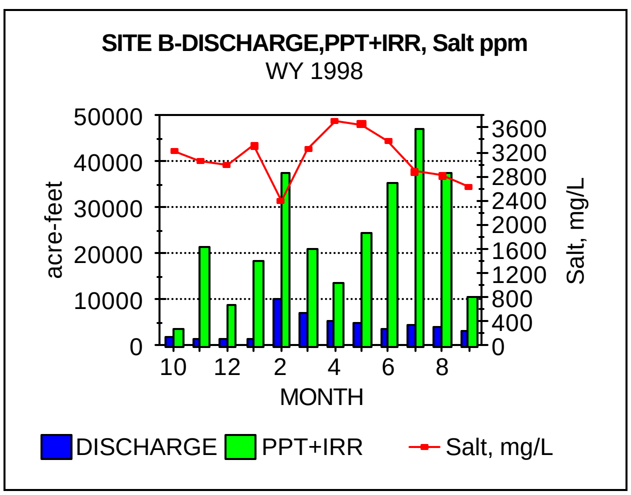


Figure D55

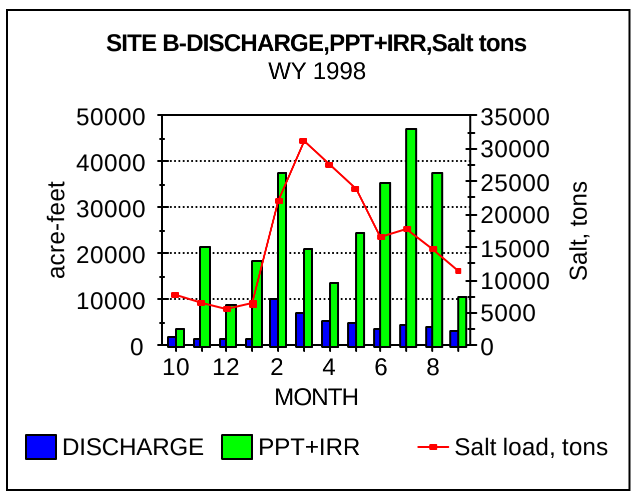


Figure D56

TABLE D1 Selenium load (lbs) from the Grassland Drainage Problem Area, Mud and Salt Sloughs, and the San Joaquin River at Patterson/Crows as a percentage of selenium load at the San Joaquin River at Vernalis.

Selenium (lbs/year)	DPA/ Vernalis (%)	Mud and Salt/Vernalis (%)	Patterson (Crows)/Vernalis (%)
1986	65	46	72
1987	126	88	101
1988	120	96	110
1989	100	93	85
1990	99	103	82
1991	162	108	98
1992	143	82	86
1993	99	77	92
1994	109	102	94
1995	69	62	83
1996	88	83	94
1997	62	69	77

TABLE D2 Salt load (TDS) from the Grassland Drainage Problem Area, Mud and Salt Sloughs, and the San Joaquin River at Patterson/Crows as a percentage of salt load at the San Joaquin River at Vernalis.

Salt (tons/year)	DPA/ Vernalis (%)	Mud and Salt/Vernalis (%)	Patterson (Crows)/Vernalis (%)
1986	17	39	78
1987	27	48	79
1988	28	54	86
1989	28	54	75
1990	25	56	79
1991	27	46	87
1992	24	43	85
1993	21	38	78
1994	24	54	84
1995	17	35	87
1996	17	40	68
1997	10	32	74

APPENDIX E

Sediment Quality and Quantity Tables

APPENDIX E

Sediment Quality and Quantity Tables

TABLES

APPENDIX E

Sediment Quality and Quantity Tables

TABLE E1 Quantity of bed sediment and suspended sediment and concentrations and loads of selenium in bed sediment of the San Luis Drain (constructed concrete channel).

Sediment in agricultural drainage canal (constructed concrete channel)	tons (dry weight)	cubic yards (dry weight)	lbs Se	ppm range/ average (dry weight)	mg/L suspended sediment (avg. input)	mg/L suspended sediment (avg. output)
San Luis Drain (1986, USBR) **28-mile segment** **85-mile segment (1984)**		 80,583 211,000	 5,280	 5 - 190/84		
San Luis Drain (1984-1993) compilation of five surveys (Presser et al., 1996)				1.4 - 210/55		
San Luis Drain (1987) (USBR et al., 1998; 1999; 2000) **28-mile segment** **85-mile segment**		 58,094 ----				
San Luis Drain 1994 (Presser et al., 1996 ; Presser and Piper, 1998) **8/94** **9/94**				 3.2 - 110/43 11 - 94/44		
San Luis Drain 1995 (Presser and Piper, 1998) **28-mile segment** **85-mile segment**		 55,788 177,900	 4,500* 14,400*			
San Luis Drain 1997 (USBR et al., 1998; 1999; 2000) **28-mile segment**		 60,593		 2.9 - 100/30 (whole core average except 0.1 value)		
San Luis Drain WY 1997 (USBR et al., 1998) (estimated from suspended solids)	465 tons deposited/year	@1.8gm/cc 308 cy @2.6 gm/cc 213 cy		no data available	102	28

* Calculated using an average concentration of selenium in SLD bed sediment of 44 ppm Se (see 1994 data).

TABLE E2 Concentration of selenium in bed sediment, suspended sediment, and plankton in natural channels.

Sediment in natural channels subjected to intermittent agricultural drainage discharge from Grassland Drainage Problem Area 1) 1950's-Sept., 1996 from Agatha Canal and Camp 13 Slough; 2) October, 1996-continuing from SLD. All sites are downstream of discharge except as noted.	Bed Sediment ppm Se (value or range) (dry weight)	Suspended Sediment ppm Se (value or range) (dry weight)	Plankton ppm Se (value or range) (dry weight)
Agatha Canal, CDFG, 1988	1.0	1.4	3.8
Camp 13 Slough, CDFG 1987	0.79		
1988	0.71-1.4	1.6-2.6	0.54-3.6
1989	0.89	3.2	3.2
East Big Lake (1992-1993, USFWS; Henderson et al., 1995) impoundment	1.0-1.8		
Mud Slough, CDFG 200m downstream of SLD (inactive)*			
1987	0.32-1.3	2.1	
1988	0.31-1.8	1.2-6.7	0.19-3.4
1989	1.1	2.4	3.8
Mud Slough (1992-1993, USFWS; Henderson et al., 1995)			
600 yards upstream of SLD discharge	0.15-0.75		
immediately downstream (120 m) of SLD (inactive)*	(average of		
6.6 miles downstream of SLD (inactive)	all sites)		
Mud Slough (1993-Sept.,1996; USBR, 1995)			
upstream of SLD discharge	<0.1-0.3		
immediately downstream of SLD (inactive)*	<0.1-0.4		
6.6 miles downstream of SLD (inactive)	<0.1-0.7		
Mud Slough (WY 1997; USBR et al., 1998)			
upstream of SLD discharge	0.10-0.44		
immediately downstream of SLD discharge	0.10-0.76		
6.6 miles downstream of SLD discharge	0.70-1.9		
Mud Slough seasonal backwater (low flow depositional area) (1993-1996; USBR, 1995)	0.3-0.6		
Mud Slough seasonal backwater (low flow depositional area) (March, 1997; USBR et al., 1998)	0.4-1.5		
Salt Slough, CDFG near hwy 165			
1987	0.31-1.3	1.4	
1988	1.1-1.4	1.2-2.6	0.17-4.2
1989	1.5	2.0	5.0
Salt Slough (1992-1993, USFWS; Henderson et al., 1995)	0.2-0.45		
Salt Slough (1993-Sept., 1996; USBR, 1995)	0.2-1.3		
Salt Slough (WY 1997; USBR et al., 1997)	0.12-0.94		
San Joaquin River, CDFG at Lander Ave. (upstream of discharge)			
1987	0.01	0.98	
1988	0.04-<0.18	1.0-1.8	<0.08-0.16
1989	<0.18	2.0	0.23
San Joaquin River (CDFG) at or below Merced River			
1987	0.19-0.75	1.7	
1988	(<0.18) 0.28-0.56	1.3-2.2	0.33-2.0
1989	0.18	1.9	2.5
San Joaquin River (CDFG) at Vernalis (Airport Blvd.; Maze Blvd; all below Stanislaus River)			
1987	0.25-1.2	1.2	
1988	<0.18-5.2	0.91-2.4	0.11-2.1
1989	--	1.4	1.2

Note: The San Luis Drain was not in use from July 1,1986 to September 23, 1996. References: CDFG = White et al., 1987; 1988;1989; Urquhart and Regalado, 1991; Henderson et al., 1995; USBR, 1995; USBR et al., 1998.

APPENDIX F

Supplemental Spreadsheets

APPENDIX F

Supplemental Spreadsheets

TABLES

F1. This scenario assumes that all freshwater exports are from the Sacramento River and that all SJR inflow enters the Bay-Delta. Sac R inflow is outflow index minus SJR discharge. Se concentration in the SJR is maintained at 2 μg Se/L. A total of 32,935 lbs of Se is released annually. Flow data are from 1997.

F2. This scenario assumes that all freshwater exports are from the Sacramento River and that all SJR inflow enters the Bay-Delta. Sac R inflow is outflow index minus SJR discharge. Se concentration in the SJR is maintained at 1 μg Se/L. A total of 16,468 lbs of Se is released annually. Flow data are from 1997.

F3. Calculation of particulate Se concentrations (μg Se/g) from inputs of the Sacramento River (Sac R), the San Joaquin River (SJR), a proposed San Luis Drain (SLD) extension, and the oil refineries under different load scenarios. Forecasts are for a wet year during the high flow season.

F4. Calculation of particulate Se concentrations (μg Se/g) from inputs of the Sacramento River (Sac R), the San Joaquin River (SJR), a proposed San Luis Drain (SLD) extension, and the oil refineries under different load scenarios. Forecasts are for a wet year during the low flow season.

F5. Calculation of particulate Se concentrations (μg Se/g) from inputs of the Sacramento River (Sac R), the San Joaquin River (SJR), a proposed San Luis Drain (SLD) extension, and the oil refineries under different load scenarios. Forecasts are for a critically dry year during the low flow season.

F6. Bioaccumulation of Se by a generic bivalve under various scenarios. Forecasts are for a wet year during the high flow season.

F7. Bioaccumulation of Se by a generic bivalve under various scenarios. Forecasts are for a wet year during the low flow season.

F8. Bioaccumulation of Se by a generic bivalve under various scenarios. Forecasts are for a critically dry year during the low flow season.

F9. Bioaccumulation of Se by a generic bivalve under various scenarios. Forecasts are for a targeted SJR load of approximately 7,000 lbs Se annually (3,400 or 3,590 lbs Se per six months).

Table F1. This scenario assumes that all freshwater exports are from the Sacramento River and that all SJR inflow enters the Bay-Delta. Sac R inflow is outflow index minus SJR discharge. Se concentration in the SJR is maintained at 2 ug Se/L. A total of 32,935 lbs of Se is released annually. Flow data are from 1997.

	Volume Avg cfs Month	*Volume MAF*	*Volume billion L*	*Concentration ug Se/L*	*Load billion ug*	*Load lbs Se*	*Contribution Sum billion ug*	*Volumes Sum billion liters*	*Concentration FW Endmember ug Se/L*	*Concentration at Carquinez Strait at 20 psu*
January										
Total OF	256565									
Sac R.	224096	13.31	16412.84	0.04	657	1,448				
SJR	32469	1.93	2378.04	2	4756	10,492				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							5,464	*18,792*	***0.29***	***0.15***
February										
Total OF	119090									
Sac R.	86950	5.16	6368.24	0.04	255	562				
SJR	32140	1.91	2353.94	2	4708	10,386				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							5,014	*8,723*	***0.57***	***0.29***
March										
Total OF	33831									
Sac R.	20944	1.24	1533.94	0.04	61	135				
SJR	12887	0.77	943.85	2	1888	4,164				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							2,000	*2,479*	***0.81***	***0.40***
April										
Total OF	13734									
Sac R.	9811	0.58	718.56	0.04	29	63				
SJR	3923	0.23	287.32	2	575	1,268				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							655	*1,007*	***0.65***	***0.33***
May										
Total OF	12261									
Sac R.	7210	0.43	528.06	0.04	21	47				
SJR	5051	0.30	369.94	2	740	1,632				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							812	*899*	***0.90***	***0.45***
June										
Total OF	8762									
Sac R.	5550	0.33	406.48	0.04	16	36				
SJR	3212	0.19	235.25	2	470	1,038				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							538	*643*	***0.84***	***0.42***

July										
Total OF	9350									
Sac R.	7326	0.44	536.56	0.04	21	47				
SJR	2024	0.12	148.24	2	296	654				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							369	*686*	***0.54***	***0.27***
August										
Total OF	9031									
Sac R.	7378	0.44	540.37	0.04	22	48				
SJR	1653	0.10	121.07	2	242	534				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							315	*662*	***0.48***	***0.24***
September										
Total OF	4555									
Sac R.	2633	0.16	192.84	0.04	8	17				
SJR	1922	0.11	140.77	2	282	621				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							341	*335*	***1.02***	***0.51***
October										
Total OF	4571									
Sac R.	2237	0.13	163.84	0.04	7	14				
SJR	2334	0.14	170.94	2	342	754				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							400	*336*	***1.19***	***0.60***
November										
Total OF	6270									
Sac R.	4095	0.24	299.92	0.04	12	26				
SJR	2175	0.13	159.30	2	319	703				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							382	*460*	***0.83***	***0.41***
December										
Total OF	18914									
Sac R.	16780	1.00	1228.97	0.04	49	108				
SJR	2134	0.13	156.29	2	313	690				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							413	*1,386*	***0.30***	***0.15***
Total Selenium Exported from SJR (lbs)						**32,935**				

Table F2. This scenario assumes that all freshwater exports are from the Sacramento River and that all SJR inflow enters the Bay-Delta. Sac R inflow is outflow index minus SJR discharge. Se concentration in SJR is maintained at 1 ug Se/L. A total of 16,468 lbs of Se is released annually. Flow data are from 1997.

Month	*Volume Avg cfs*	*Volume MAF*	*Volume billion L*	*Concentration ug Se/L*	*Load billion ug*	*Load lbs Se*	*Contribution Sum billion ug*	*Volumes Sum billion liters*	*Concentration FW Endmember ug Se/L*	*Concentration at Carquinez Strait at 20 psu*
January										
Total OF	256565									
Sac R.	224096	13.31	16412.84	0.04	657	1,448				
SJR	32469	1.93	2378.04	1	2378	5,246				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							3,086	*18,792*	***0.16***	***0.08***
February										
Total OF	119090									
Sac R.	86950	5.16	6368.24	0.04	255	562				
SJR	32140	1.91	2353.94	1	2354	5,193				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							2,660	*8,723*	***0.30***	***0.15***
March										
Total OF	33831									
Sac R.	20944	1.24	1533.94	0.04	61	135				
SJR	12887	0.77	943.85	1	944	2,082				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							1,057	*2,479*	***0.43***	***0.21***
April										
Total OF	13734									
Sac R.	9811	0.58	718.56	0.04	29	63				
SJR	3923	0.23	287.32	1	287	634				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							367	*1,007*	***0.36***	***0.18***
May										
Total OF	12261									
Sac R.	7210	0.43	528.06	0.04	21	47				
SJR	5051	0.30	369.94	1	370	816				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							442	*899*	***0.49***	***0.25***
June										
Total OF	8762									
Sac R.	5550	0.33	406.48	0.04	16	36				
SJR	3212	0.19	235.25	1	235	519				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							303	*643*	***0.47***	***0.24***

July										
Total OF	9350									
Sac R.	7326	0.44	536.56	0.04	21	47				
SJR	2024	0.12	148.24	1	148	327				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							221	*686*	***0.32***	***0.16***
August										
Total OF	9031									
Sac R.	7378	0.44	540.37	0.04	22	48				
SJR	1653	0.10	121.07	1	121	267				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							194	*662*	***0.29***	***0.15***
September										
Total OF	4555									
Sac R.	2633	0.16	192.84	0.04	8	17				
SJR	1922	0.11	140.77	1	141	311				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							200	*335*	***0.60***	***0.30***
October										
Total OF	4571									
Sac R.	2237	0.13	163.84	0.04	7	14				
SJR	2334	0.14	170.94	1	171	377				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							229	*336*	***0.68***	***0.34***
November										
Total OF	6270									
Sac R.	4095	0.24	299.92	0.04	12	26				
SJR	2175	0.13	159.30	1	159	351				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							223	*460*	***0.48***	***0.24***
December										
Total OF	18914									
Sac R.	16780	1.00	1228.97	0.04	49	108				
SJR	2134	0.13	156.29	1	156	345				
SLD		0.00	0.00	62.5	0	0				
Refineries		0.00	1.03	50	51	113				
							257	*1,386*	***0.19***	***0.09***
Total Selenium Exported from SJR (lbs)						**16,468**				

Table F3. Calculation of particulate Se concentrations (ug Se/g) from inputs of the Sacramento River (Sac R), the San Joaquin River (SJR), a proposed San Luis Drain (SLD) extension, and the oil refineries under different load scenarios. Forecasts are for a wet year during the high flow season.

	Volume MAF	*Load lbs Se per 6 months*	*Concentration ug Se/L in source*	*Concentration FW Endmember ug Se/L*	*Concentration at Carquinez Strait at 20 psu*	*Particulate Concentration* Kd = 1,000 *FW Endmember ug Se/g*	*Carquinez Strait*	Kd=3,000 *FW Endmember*	*Carquinez Strait*	Kd = 10,000 *FW Endmember*	*Carquinez Strait*
1. San Luis Drain Scenarios: Wet year (1997 data); High Flow Season											
a) SLD at half capacity (150 cfs), 50 ppb Se (6,800 lbs in six months); SJR reaches the Bay-Delta.											
Sac R.	17	1,850	0.04								
SJR	2	5,440	1								
SLD	0.05	6,800	50								
Refineries	0.005	680	50								
				0.28	***0.14***	***0.280***	***0.140***	***0.840***	***0.420***	***2.800***	***1.400***
b) SLD at full capacity (300cfs), 62.5 ppb Se (18,700 lbs in six months); SJR reaches Bay-Delta.											
Sac R.	17	1,850	0.04								
SJR	2	5,440	1								
SLD	0.11	18,700	62.5								
Refineries	0.005	680	50								
				0.51	***0.26***	***0.510***	***0.260***	***1.530***	***0.780***	***5.100***	***2.600***
c) SLD at full capacity (300 cfs), 150 ppb Se (44,880 lbs in six months); SJR reaches Bay-Delta.											
Sac R.	17	1,850	0.04								
SJR	2	5,440	1								
SLD	0.11	44,820	150								
Refineries	0.005	680	50								
				1.02	***0.51***	***1.020***	***0.510***	***3.060***	***1.530***	***10.200***	***5.100***
d) SLD at full capacity (300cfs), 300 ppb Se (89,760 lbs in six months); SJR reaches Bay											
Sac R.	17	1,850	0.04								
SJR	2	5,440	1								
SLD	0.11	89,760	300								
Refineries	0.005	680	50								
				1.88	***0.94***	***1.880***	***0.940***	***5.640***	***2.820***	***18.800***	***9.400***
Targeted SJR load 7,180 lbs annually; 3,590 lbs in six months; full conveyance to the Bay-Delta.											
Sac R.	17	1,850	0.04								
SJR	1.1	3,590	1.2								
SLD	0	0	0								
Refineries	0.005	680	50								
				0.12	***0.06***	***0.120***	***0.060***	***0.360***	***0.180***	***1.200***	***0.600***
A "restoration scenario" for the SJR; (No SLD extension, refinery cleanup).											
Sac R.	17	1,850	0.04								
SJR	2.25	3,060	0.5								
SLD	0	0	0								
Refineries	0.005	680	50								
				0.11	***0.05***	***0.110***	***0.050***	***0.330***	***0.150***	***1.100***	***0.500***

Table F4. Calculation of particulate Se concentrations (ug Se/g) from inputs of the Sacramento River (Sac R), the San Joaquin River (SJR), a proposed San Luis Drain (SLD) extension, and the oil refineries under different load scenarios. Forecasts are for a wet year during the low flow season.

	Volume MAF	*Load lbs Se per 6 months*	*Concentration ug Se/L in source*	*Concentration FW Endmember ug Se/L*	*Concentration at Carquinez Strait at 20 psu*	*Particulate Concentration* Kd = 1,000 *FW Endmember ug Se/g*	*Carquinez Strait*	Kd=3,000 *FW Endmember*	*Carquinez Strait*	Kd = 10,000 *FW Endmember*	*Carquinez Strait*
2. San Luis Drain Scenarios: Wet Year (1997 data); Low Flow Season											
a) SLD at half capacity (150 cfs), 50 ppb Se (6,800 lbs in six months); little SJR reaches Bay-Delta.											
Sac R.	2.3	250	0.04								
SJR	0.001	3	2								
SLD	0.05	6,800	50								
Refineries	0.005	680	50								
				1.21	***0.6***	***1.210***	***0.600***	***3.630***	***1.800***	***12.100***	***6.000***
b) SLD at full capacity (300cfs), 62.5 ppb Se (18,700 lbs in six months); little SJR reaches Bay-Delta.											
Sac R.	2.3	250	0.04								
SJR	0.001	5	2								
SLD	0.11	18,700	62.5								
Refineries	0.005	680	50								
				2.99	***1.49***	***2.990***	***1.490***	***8.970***	***4.470***	***29.900***	***14.900***
c) SLD at full capacity (300 cfs), 150 ppb (44,880 lbs in six months); little SJR reaches Bay-Delta.											
Sac R.	2.3	250	0.04								
SJR	0.001	5	2								
SLD	0.11	44,820	150								
Refineries	0.005	680	50								
				6.97	***3.49***	***6.970***	***3.490***	***20.910***	***10.470***	***69.700***	***34.900***
d) SLD at full capacity (300 cfs), 300 ppb Se (89,760 lbs in six months); little SJR reaches Bay-Delta.											
Sac R.	2.3	250	0.04								
SJR	0.001	5	2								
SLD	0.11	89,760	300								
Refineries	0.005	680	50								
				13.80	***6.9***	***13.800***	***6.900***	***41.400***	***20.700***	***138.000***	***69.000***
Targeted SJR load of 6,800 lbs annually; 3,400 lbs in six months; full conveyance to the Bay-Delta.											
Sac R.	2.3	250	0.04								
SJR	0.5	3,400	2.5								
SLD	0	0	0								
Refineries	0.005	680	50								
				0.57	***0.28***	***0.570***	***0.280***	***1.710***	***0.840***	***5.700***	***2.800***
A "restoration scenario" for the SJR (No SLD extension, refinery cleanup).											
Sac R.	2.3	250	0.04								
SJR	0.75	1,020	0.5								
SLD	0	0	0								
Refineries	0.005	680	50								
				0.23	***0.12***	***0.230***	***0.120***	***0.690***	***0.360***	***2.300***	***1.200***

Table F5. Calculation of particulate Se concentrations (ug Se/g) from inputs of the Sacramento River (Sac R), the San Joaquin River (SJR), a proposed San Luis Drain (SLD) extension, and the oil refineries under different load scenarios. Forecasts are for a critically dry year during the low flow season.

	Volume MAF	*Load lbs Se per 6 months*	*Concentration ug Se/L in source*	*Concentration FW Endmember ug Se/L*	*Concentration at Carquinez Strait at 20 psu*	*Particulate Concentration* Kd = 1,000 *FW Endmember ug Se/g*	*Carquinez Strait*	Kd=3,000 *FW Endmember*	*Carquinez Strait*	Kd = 10,000 *FW Endmember*	*Carquinez Strait*
3. San Luis Drain Scenarios: Critically Dry Year (1994 data); Low Flow Season											
a) SLD at half capacity (150 cfs), 50 ppb Se (6,800 lbs in six months); little SJR reaches Bay-Delta.											
Sac R.	1.3	141	0.04								
SJR	0.0005	3	2								
SLD	0.05	6,800	50								
Refineries	0.005	680	50								
				2.07	***1.03***	***2.070***	***1.030***	***6.210***	***3.090***	***20.700***	***10.300***
b) SLD at full capacity (350 cfs), 62.5 ppb Se (18,700 lbs Se in six months); little SJR reaches Bay-Delta.											
Sac R.	1.3	141	0.04								
SJR	0.0005	3	2								
SLD	0.11	18,700	62.5								
Refineries	0.005	680	50								
				5.07	***2.54***	***5.070***	***2.540***	***15.210***	***7.620***	***50.700***	***25.400***
c) SLD at full capacity (300 cfs), 150 ppb Se (44,880 lbs in six months); little SJR reaches Bay-Delta.											
Sac R.	1.3	141	0.04								
SJR	0.001	5	2								
SLD	0.11	44,880	150								
Refineries	0.005	680	50								
				11.87	***5.93***	***11.870***	***5.930***	***35.610***	***17.790***	***118.700***	***59.300***
d) SLD at full capacity (300 cfs), 300 ppb Se (89,760 lbs in six months); little SJR reaches Bay-Delta.											
Sac R.	1.3	141	0.04								
SJR	0.0005	3	2								
SLD	0.11	89,760	300								
Refineries	0.005	680	50								
				23.53	***11.76***	***23.530***	***11.760***	***70.590***	***35.280***	***235.300***	***117.600***
Targeted SJR load of 7,180 lbs annually (3,590 lbs in six months); full conveyance to Bay-Delta.											
Sac R.	2.3	250	0.04								
SJR	0.5	3,400	2.5								
SLD	0	0	0								
Refineries	0.005	680	50								
				0.86	***0.43***	***0.860***	***0.430***	***2.580***	***1.290***	***8.600***	***4.300***
A "restoration scenario" for the SJR (No SLD extension, refinery cleanup).											
Sac R.	1.6	174	0.04								
SJR	0.28	381	0.5								
SLD	0	0	0								
Refineries	0.005	680	50								
				0.24	***0.12***	***0.240***	***0.120***	***0.720***	***0.360***	***2.400***	***1.200***

Table F6. Bioaccumulation of Se by a generic bivalve under various scenarios.

AE1=0.35 AE2=0.55 AE3=0.63 AE4=0.8 Ke=0.03 IR=0.2

AE = assimilation efficiency; Kd = distribution (partitioning) coefficient; Ke = rate constant of loss; IR = ingestion rate

	1A	1B	2A	2B	3A	3B
	Kd = 1,000		Kd=3,000		Kd = 10,000	
	FW Endmember	***Carquinez Strait***	***FW Endmember***	***Carquinez Strait***	***FW Endmember***	***Carquinez Strait***
All values in the table below are ug Se/g dry weight.						
Scenario: Wet year (1997 data); High flow season						
SLD at half capacity (150 cfs), 50 ppb Se (6,800 lbs in six months); SJR reaches Bay-Delta.						
Particles	***0.280***	***0.140***	***0.840***	***0.420***	***2.800***	***1.400***
AE1	**0.8**	**0.4**				
AE2			**3.9**	**1.9**		
AE3					**14.7**	**7.4**
AE4					**18.7**	**9.3**
SLD at full capacity (300 cfs), 62.5 ppb Se (18,700 lbs Se in six months); SJR reaches Bay-Delta						
Particles	***0.510***	***0.260***	***1.530***	***0.780***	***5.100***	***2.600***
AE1	**1.5**	**0.8**				
AE2			**7.0**	**3.6**		
AE3					**26.8**	**13.7**
AE4					**34.0**	**17.3**
SLD at full capacity (300 cfs); 150 ppb Se (44,880 lbs in six months); SJR reaches Bay						
Particles	***1.020***	***0.510***	***3.060***	***1.530***	***10.200***	***5.100***
AE1	**3.0**	**1.5**				
AE2			**14.0**	**7.0**		
AE3					**53.6**	**26.8**
AE4					**68.0**	**34.0**
Prior to refinery cleanup (No SLD extension)						
Particles	***0.220***	***0.110***	***0.660***	***0.330***	***2.180***	***1.100***
AE1	**0.96**	**0.48**				
AE2			**4.54**	**2.27**		
AE3					**17.17**	**8.66**
AE4					**21.80**	**11.00**

Table F7. Bioaccumulation of Se by a generic bivalve under various scenarios.

AE1=0.35 AE2=0.55 AE3=0.63 AE4=0.8 Ke=0.03 IR=0.2

AE = assimilation efficiency; Kd = distribution (partitioning) coefficient; Ke = rate constant of loss; IR = ingestion rate

	1A	1B	2A	2B	3A	3B
	Kd = 1,000		Kd=3,000		Kd = 10,000	
	FW Endmember	***Carquinez Strait***	***FW Endmember***	***Carquinez Strait***	***FW Endmember***	***Carquinez Strait***

All values in the table below are ug Se/g dry weight.

Scenario: Wet Year (1997 data); Low flow season

SLD at half capacity (150 cfs), 50 ppb Se (6,800 lbs in six months); little SJR reaches Bay-Delta.						
Particles	***1.2***	***0.6***	***3.6***	***1.8***	***12.1***	***6.0***
AE1	**3.5**	**1.8**				
AE2			**16.6**	**8.3**		
AE3					**63.5**	**47.3**
AE4					**80.7**	**60.0**
SLD at full capacity (300 cfs), 62.5 ppb Se (18,700 lbs Se in six months); little SJR reaches Bay-Delta						
Particles	***3.0***	***1.5***	***9.0***	***4.5***	***29.9***	***14.9***
AE1	**8.7**	**4.3**				
AE2			**41.1**	**20.5**		
AE3					**157.0**	**117.34**
AE4					**199.3**	**149.00**
SLD at full capacity (300 cfs), 150 ppb Se (44,880 lbs in six months); little SJR reaches Bay-Delta						
Particles	***7.0***	***3.5***	***20.9***	***10.5***	***69.7***	***34.9***
AE1	**20.3**	**10.2**				
AE2			**95.8**	**48.0**		
AE3					**365.9**	**274.84**
AE4					**464.7**	**349.00**
Prior to refinery cleanup (No SLD extension)						
Particles	***0.390***	***0.200***	***1.170***	***0.600***	***3.900***	***2.000***
AE1	**1.71**	**0.88**				
AE2			**8.04**	**4.13**		
AE3					**30.71**	**15.75**
AE4					**39.00**	**20.00**

Table F8. Bioaccumulation of Se by a generic bivalve under various scenarios.

AE1=0.35 AE2=0.55 AE3=0.63 AE4=0.8 Ke=0.03 IR=0.2

AE = assimilation efficiency; Kd = distribution (partitioning) coefficient; Ke = rate constant of loss; IR = ingestion rate

All values in the table below are ug Se/g dry weight.

	1A	1B	2A	2B	3A	3B
	Kd = 1,000		Kd=3,000		Kd = 10,000	
	FW Endmember	***Carquinez Strait***	***FW Endmember***	***Carquinez Strait***	***FW Endmember***	***Carquinez Strait***
Scenario: Critically Dry Year; Low flow season						
SLD at half capacity (150 cfs), 50 ppb Se (6,800 lbs in six months); little SJR reaches Bay-Delta.						
Particles	***2.1***	***1.0***	***6.2***	***3.1***	***20.7***	***10.3***
AE1	**6.1**	**2.9**				
AE2			**28.4**	**14.2**		
AE3					**108.7**	**81.1**
AE4					**138.0**	**103.0**
SLD at full capacity (300 cfs), 62.5 ppb Se (18,700 lbs Se in six months); little SJR reaches Bay-Delta.						
Particles	***5.1***	***2.5***	***15.2***	***7.6***	***50.7***	***25.4***
AE1	**14.9**	**7.3**				
AE2			**69.7**	**34.8**		
AE3					**266.2**	**200.03**
AE4					**338.0**	**254.00**
SLD at full capacity (300 cfs), 150 ppb Se (44,880 lbs in six months); little SJR reaches Bay-Delta.						
Particles	***11.9***	***5.9***	***35.6***	***17.8***	***119.0***	***59.0***
AE1	**34.7**	**17.2**				
AE2			**163.2**	**81.6**		
AE3					**624.8**	**464.6**
AE4					**793.3**	**590.0**
Prior to refinery cleanup (No SLD extension).						
Particles	***0.530***	***0.270***	***1.590***	***0.810***	***5.300***	***2.700***
AE1	**2.32**	**1.18**				
AE2			**10.93**	**5.57**		
AE3					**41.74**	**21.26**
AE4					**53.00**	**27.00**

Table F9. Bioaccumulation of Se by a generic bivalve under various scenarios.

AE1=0.35 AE2=0.55 AE3=0.63 AE4=0.8 Ke=0.03 IR=0.2

AE = assimilation efficiency; Kd = distribution (partitioning) coefficient; Ke = rate constant of loss; IR = ingestion rate

	1A	1B	2A	2B	3A	3B
	Kd = 1,000		Kd=3,000		Kd = 10,000	
	FW Endmember	***Carquinez Strait***	***FW Endmember***	***Carquinez Strait***	***FW Endmember***	***Carquinez Strait***
All values in the table below are ug Se/g dry weight.						
Targeted SJR Load of approximately 7,000 lbs Se annually (3,400 or 3,590 lbs Se in six months)						
Critically Dry Year; Low Flow Season						
Particles	***0.86***	***0.43***	***2.58***	***1.29***	***8.60***	***4.30***
AE1	**2.5**	**1.3**				
AE2			**11.8**	**5.9**		
AE3					**45.2**	**33.9**
AE4					**57.3**	**43.0**
Wet Year; Low Flow Season						
Particles	***0.57***	***0.28***	***1.71***	***0.84***	***5.70***	***2.80***
AE1	**1.7**	**0.8**				
AE2			**7.8**	**3.9**		
AE3					**29.9**	**22.05**
AE4					**38.0**	**28.00**
Wet Year; High Flow Season						
Particles	***0.12***	***0.06***	***0.36***	***0.18***	***1.20***	***0.60***
AE1	**0.4**	**0.2**				
AE2			**1.7**	**0.8**		
AE3					**6.3**	**4.7**
AE4					**8.0**	**6.0**