Chapter 5

Zone 7 Salt Balance Calculations

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5.1 Introduction

Maintaining a sustainable water supply and a sustainable water quality are key components of successful groundwater basin management and stewardship. To provide a sustainable water supply, a basin must be managed to prevent overdraft. To provide sustainable water quality, a basin must be managed to have a neutral or negative salt balance. The purpose of this chapter is to describe and summarize the salt balance calculations used to monitor the loading to, and thus the sustainability of, the Main Basin groundwater quality.

A sustainable water supply has been assured through Zone 7's practice of maintaining the groundwater basin in long-term hydrologic balance. Overdraft is prevented through a combination of monitoring, detailed inventory tracking, contracts that limit pumping, education/negotiation with prospective extractors, and finally, a commitment to artificially recharge the basin as needed to maintain the basin hydrologic balance.

Attaining sustainable groundwater quality is a Zone 7 goal that has yet to be fully achieved. Zone 7 believes that this goal can be achieved through the control and adjustment of the computed salt balance of the basin. Zone 7 annually computes a basin salt balance using a fundamental salt balance equation: inflow of salts dissolved in water minus outflow of salts dissolved in water equals the change in dissolved salts in the basin.

Zone 7 computes the magnitude of components in the salt balance equation using its extensive hydrologic inventory database. Salts are added to the basin in via various sources of recharge. Natural stream recharge adds water and salt from the Arroyo Valle, Arroyo Mocho and Arroyo Las Positas. Irrigation of urban and agricultural lands adds salt dissolved in the irrigation water. Subsurface inflow from the fringe basins adds water and salts as groundwater flows into the basin. Artificial stream recharge adds water and salts dissolved in the recharge waters. Rainfall does not add salt. However it helps dilute and transport the salts added from urban and agricultural irrigation down to the water table.

Salts are removed from the basin by several hydrologic outflow components. Salts are removed from the Main Basin as water is pumped from wells or gravel mining pits. Some of the extracted municipal pumpage and associated salt (25-30%) is returned to the basin in that portion used for irrigation over the Main Basin. The remainder of the pumpage and salts is either used inside the home and then exported as wastewater in the LAVWMA pipeline or used for irrigation in fringe basin areas where the applied salts do not impact the Main Basin. Some of the mining pumpage is returned to the Main Basin through stream recharge. However, most of this pumpage leaves the basin and valley as stream outflow. Irrigation within the basin removes water through evaporation. However, no salt is removed (the salt remains with the excess irrigation water (percolate) in the soil). Similarly, evaporation removes water from the mining ponds but leaves behind dissolved minerals.

5.2 Salt Loading Calculation Assumptions

One of Zone 7's groundwater basin management tools is the tracking and annual calculation of salt loading to the Main Basin. These salt balance calculations take into account the addition and removal of salt in the Main Basin based on annual water supply and demand. The influx of salts into the Main Basin comes from natural stream recharge, urban irrigation, agricultural irrigation, subsurface groundwater inflow, and artificial recharge. The removal of salts from the Main Basin occurs through groundwater pumpage from the basin for municipal and agricultural purposes, gravel mining related stream exports and off-haul, and groundwater basin outflow. Therefore, the salt balance presents an estimate of the overall effect of salt loading on groundwater quality in the basin based on salt loading at the surface. The final results of the salt balance are presented as annual cumulative changes in the basin-wide TDS concentration and salt loading.

The salt balance calculations include several fundamental and intentionally simplifying assumptions as part of this screening level "spreadsheet" model of the Main Basin. It is assumed that the main groundwater basin is well mixed. Supply and demand components each have associated TDS concentrations based on the given year's monitoring data, some historic data, and a few assumed (otherwise unmeasurable) values. Perhaps the most important simplifying assumption is that all salts applied through irrigation eventually make their way to the underlying groundwater (while in actuality vadose zone processes can delay salt transport for decades). Salts removed by plant uptake and by the application of fertilizers are considered negligible. Percolate quality is assumed to be primarily a function of the differing percent of applied water that recharges throughout the area due to site specific variations in soil characteristics.

Zone 7 performs salt loading calculations in two ways. The first method uses a given year's (e.g., 1998) actual rainfall and recharge volume and water quality data plus that year's land use conditions. This actual annual salt balance is computed using Zone 7's detailed hydrologic inventory data and has been calculated since 1974. The actual balance in any one year is not indicative of long-term trends since there can be substantial year to year variations in recharge and extraction components and also significant changes in basin storage. Very wet years, for example, may show a negative salt balance. A large drop in basin storage due to a drought for example will result in less water in the basin and generally a net loss of salts even though the concentration of salts may increase.

Conversely, large net salt loads will be shown in years following drought and basin drawdown when the basin is being refilled and there is less mining export.

Given the limitations of annual salt loading calculations for long-term planning and salt management decision-making purposes, Zone 7 also calculates what is called the steady state salt balance. These steady state calculations yield the average expected recharge and salt loading for a given set of land use conditions (e.g., water demand and urbanized acreage over the Main Basin). The steady state salt balance is a normalized salt balance, not a simple moving average of the measured values reported in each of the annual salt balances that have been calculated since 1974.

It is normalized in the sense that changes that would permanently alter a parameter (such as increased channelization increasing Arroyo Mocho recharge capacity) are not just averaged in but are incorporated into the underlying calculations. A specific example of the need for normalization is salt outflow via agricultural pumpage. From 1974 through 1990, annual agricultural pumpage ranged from about 1400 AF to almost 5000 AF (Reference J, Table 3A). Since 1990 values dropped to about the 200 AF range as groundwater was replaced with untreated SBA water, and reached a low of about 100 AF in high rainfall 1998. Using the simple long-term 1974-1998 average of 1734 AF would be unrepresentative of current and likely future average conditions, as would using 100 AF from the wet 1998 year. Therefore, for the steady-state calculations for 1998 land use conditions in Table 5.2, Zone 7 staff chose to use a value of 200 AF as representative of current average conditions.

This normalization reflects the fact that these types of operational and land use changes (and other changes such as the amount of irrigated urban and agricultural acreage) will alter salt loading from that year forward. This steady state approach provides a more accurate and useful reflection of average conditions that would exist in the future compared to a simple moving average. The steady state salt balance is thus designed to be more of a predictive rather than retrospective indicator of salt loadings.

The normalized salt balance is adjusted to balance supply and demand hydrology so there is no net change in storage. This adjustment eliminates changes in predicted concentration and loading simply due to changes in Main Basin volume.

Water quality (TDS) values for each component are adjusted each year to the long-term flow weighted average. Values for parameters that are primarily weather dependent, such as natural stream recharge, are also long-term average values. For example, the steady-state rainfall recharge of 4,100 AF would be the average rainfall recharge if 1998 land use conditions had existed for a series of years experiencing weather conditions equivalent to those occurring in 1974-1998.

These steady state salt balances constructed using current land characteristics describe what should be expected given current land use, average weather, and average groundwater supply and demand. The steady state calculations are useful in part for tracking long-term expected TDS impacts on the basin. They are also useful, as described in Chapter IX, when adjusted for future year (i.e., 2010) land use and operational conditions, to evaluate the impacts of alternative salt management strategies.

5.3 Explanation of Salt Balance Summary Tables

This section provides a short description of the major components included in computing the 1998 Main Basin salt balance. A more detailed explanation including copies of the various worksheets documenting the underlying calculations and assumptions is contained in the Zone 7 June 2, 2000 memorandum "Main Groundwater Basin Salt Balance, 1974-1998 WY" (Reference J). The salt balance tables 5.1 (1998 Water Year) and 5.2 (Steady State) from the salt balance memo are broken into Supply and Demand Subsections. The Supply subsection has columns corresponding to applied water, recharge water, salt load in tons, and salt load in tons per 1,000 acre-feet of recharge. The Demand subsection has columns for water removed, salt load removed in tons, and salt removed in tons per 1,000 AF of recharge.

The applied water and recharge water values in the supply subsection are generally the same for each of the components except in cases of irrigation water. Variable amounts of applied water end up recharging the basin (based on site specific soil type, irrigation efficiencies, and other variables), so that calculated recharge water (i.e., percolate) quality varies. All the salts applied in irrigation water are assumed to reach the basin. The salt load and salt load in tons per 1,000 acre-feet of recharge are computed using the values in the recharge water columns. Each of the major line items is briefly described below.

Salt Sources (Supply Components)

Rainfall recharge is calculated using a Zone 7 simulation model and is assumed to contain no salt. Rainfall recharge therefore adds no new salts to the Main Basin. The rainfall recharge for 1998 steady state conditions was determined using 1998 land use conditions and 1974-1998 hydrology.

Arroyo Valle recharge is divided into four sub-components: Lake/imported water recharge, flood release recharge, upper reach natural inflow recharge, and lower reach natural inflow recharge. Each flow component is calculated on a daily basis. The TDS of lake imported water recharge and flood release recharge water are assumed to be the same as the monthly TDS of Del Valle Water Treatment Plant inflow. The TDS of upper reach natural inflow recharge water is determined from the monthly electrical conductivity at the Arroyo Valle near Livermore gaging station, and the TDS of lower reach natural recharge water is assumed to be 250 mg/L. The annual TDS for each of these sub-components is calculated as a flow-weighted monthly average.

Arroyo Mocho natural recharge and **Arroyo Las Positas natural recharge** are determined as a part of the Zone 7 hydrologic inventory. Flow components are calculated daily and the TDS of the recharge water for each month is determined from the monthly electrical conductivity at the Arroyo Mocho near Livermore and Arroyo Las Positas near Livermore gaging stations, respectively. Based upon monthly recharge and monthly TDS, flow weighted average TDS values are then determined.

Urban irrigation volume is calculated by using purveyors' metered water use (Zone 7 deliveries plus purveyor pumpage), the ratio of urban area inside the Main Basin to the total urban area serviced by each purveyor, and the assumption that water used in a month in excess of the minimum use month for the year is used for external irrigation. It is assumed that a given percentage of each type of irrigation water evaporates without recharging, and that all of the applied salts concentrate in the remaining, recharging water (see Reference J for a more detailed description of the calculations and assumptions).

LWRP reclaimed water volume used for irrigation is metered and reported monthly along with corresponding TDS. Based upon the monthly applied water amount and monthly TDS, a flow-weighted average TDS is determined. Future recycled water irrigation would be added to and tracked under this category.

SBA agricultural irrigation volume is determined using monthly metered deliveries for agricultural use and the ratio of SBA agricultural irrigated area inside the Main Basin to the total SBA agricultural irrigated area. This ratio of the area is determined from the current land use map. Most of the **groundwater agricultural irrigation** over the Main Basin is not metered. The amount of this component is determined using the Zone 7 Rainfall and Applied Water Recharge Model. The TDS of this component is assumed to be the same as the TDS of municipal pumpage.

Subsurface groundwater inflow (from the northwest portion of the fringe/main basin interface) is included as part of the hydrologic inventory and the TDS is estimated as approximately 1500 mg/L based on monitoring well data.

Artificial supplemental recharge on Arroyo Valle, Arroyo Mocho and Injection Well Recharge are the only three artificial recharge components at this time. The daily amounts of recharge for these three sub-components are determined as part of the Zone 7 hydrologic inventory. Monthly TDS of PPWTP inflow is designated as the TDS of artificial recharge at Arroyo Mocho and monthly TDS of DVWTP inflow is designated as the TDS of artificial recharge at Arroyo Valle plus injection at the Hopyard #6 ASR well. Based upon the monthly recharge amounts and monthly TDS, flow weighted TDS values are determined.

Salt Export (Demand Components)

Municipal groundwater pumpage consists of the pumpage by Zone 7, Pleasanton, CWS, DSRSD, SFWD, domestic users, Alameda County Fairgrounds, Livermore, Castlewood Golf Course and Tri-Valley Golf Center. Most of the municipal pumpage is metered and reported monthly by well. Based upon the available quarterly or annual data, a TDS value is assigned to each well contributing to the municipal pumpage. The TDS and the annual production from each well are used to determine a flow weighted average municipal pumpage concentration. Assumptions are the same as for urban irrigation (above) about the relative amount of pumpage and salts exported based on how and where the water is used.

Agricultural groundwater pumpage inside the Main Basin is mostly calculated from annual land use measurements, because most of this pumpage is not metered. The TDS of this pumpage is assumed to be the same as the TDS of the Zone 7 pumpage. The volume of **mining export** is determined as a routine part of the Zone 7 hydrologic inventory. Based upon the monthly mining area monitoring program, a monthly representative TDS for each gravel mining company's exports is assigned. Flow-weighted annual average TDS for water exports are determined based upon the monthly export amounts and TDS. The volume of **gravel mining off-haul** water by gravel mining companies is estimated at 700 AF per year. The TDS of this water is assumed to be 500 mg/L. The amount of **subsurface groundwater outflow** is determined as part of the Zone 7 hydrologic inventory. The TDS of the outflow water is determined by averaging the TDS of shallow wells in the vicinity of the Arroyo Valle and Arroyo de la Laguna confluence.

5.4 Actual 1998 Water Year Salt Balance Results

Table 5.1 presents the main groundwater salt balance for the 1998 water year. The 1998 water year was an unusually wet (only a 10% chance that a given year would be wetter) and therefore very favorable year for the salt balance. There was an estimated increase in storage of approximately 3,800 AF and decrease in (i.e., negative) salt loading to the Main Basin of 4,760 tons. The average TDS of recharged water in 1998 was 310 mg/L. The main factors causing the favorable 1998 salt balance are the 12,868 AF of rainfall recharge with no salts and above normal water and salt exports (12,617 AF with 9,080 tons of salt) by the gravel mining companies. For comparison, the normal steady state rainfall recharge at 1998 land use conditions, based on weather from 1974 through 1998 is 4,100 AF and average water and salt export by gravel mining companies is about 8,700 AF and 6,150 tons, respectively (see Table 5.2).

Figures 5.1 – 5.3 present a condensed tabular and schematic summary of Table 5.1 (actual 1998) data plus the relative percent salt loading contributed or removed by the major sources. The figures are intended to help convey a fundamental understanding of where the salts come from (gross loading), how salts get removed from the basin, and how net

TABLE 5.1

Main Basin Salt Balance
1998 WATER YEAR

WATER SUPPLY COMPONENTS	APPLIED WATER		RECHARGE WATER		SALT LOAD IN TONS	SALT LOAD IN TONS PER 1,000 ACRE-FOOT OF RECHARGE
	ACRE-FEET	TDS IN mg/l	ACRE-FEET	TDS IN mg/l		
NATURAL						
RAINFALL RECHARGE	12868		12,868	0	0	
ARROYO VALLE						
Lake/imported water recharge	958	190	958	190	250	260
Flood releases recharge	2,145	180	2,145	180	520	240
Upper reach natural inflow	1,214	340	1,214	340	560	460
Lower reach natural inflow	1,043	250	1,043	250	350	340
Total Arroyo Valle	5,360	232	5,360	232	1,680	
ARROYO MOCHO NATURAL RECHARGE	4,560	370	4,560	370	2,290	500
ARROYO LAS POSITAS NATURAL RECHARGE	1,572	820	1,572	820	1,750	1,110
URBAN IRRIGATION						
SBA water	5,298	200	570	1,859	1,440	2,530
Groundwater						
Zone 7 Groundwater, extraction only wells (NO RO	421	400	40	4,210	230	5,750
Zone 7 Groundwater, extraction only wells (RO)	0		0		0	
Zone 7 Groundwater, ASR wells	0		0		0	
Groundwater, others (no RO)	3,183	480	330	4,630	2,080	6,300
Domestic groundwater pumpage	68	450	68	450	40	590
LWRP reclaimed water irrigation	412	490	40	5,048	270	6,750
Total urban irrigation	9,382	319	1,048	2,851	4,060	
AGRICULTURAL IRRIGATION						
SBA water	1,212	170	288	715	280	970
Groundwater	108	470	15	3,384	70	4,670
Total agricultural irrigation	1,320	195	303	848	350	
Subsurface groundwater inflow	810	1,500	810	1,500	1,650	2,040
Total Natural Supply	35,872		26,521		11,780	
ARTIFICIAL SUPPLEMENTAL RECHARGE						
Arroyo Valle	182	190	182	190	50	270
Arroyo Mocho	1,930	150	1,930	150	390	200
Injection Well Recharge	571	230	571	230	180	320
RO Recycled Water Injection / Stream Recharge	0				0	
RO Recycled Water Irrigation	0				0	
Total artificial recharge	2,683		2,683		620	460
TOTAL SUPPLY	38,550	240	29,204	310	12,400	

WATER DEMAND COMPONENTS	WATER REMOVED		SALT LOAD IN TONS	SALT REMOVED IN TONS PER 1,000 ACRE-FOOT OF EXPORT
	ACRE-FEET	TDS IN mg/l		
MUNICIPAL PUMPAGE				
Zone 7 municipal pumpage, ASR wells	0			
Zone 7 municipal pumpage, extraction only wells	1,682	400	910	540
Other municipal pumpage	8,585	480	5,600	650
Total municipal pumpage	10,267	470	6,510	
AGRICULTURAL PUMPAGE	108	470	70	650
MINING EXPORT	12,617	530	9,080	720
MINING OFFHAUL	700	530	500	710
POND EVAPORATION	925			
SUBSURFACE GROUNDWATER OUTFLOW	750	980	1,000	1,330
TOTAL DEMAND	25,367	500	17,160	
NET RECHARGE/ NET SALT BALANCE	3,837		(4,760)	

1998 Groundwater Main Basin Salt Load

	Applied Water		Recharge Water		Salt Load	
Salt source	**Volume (AF)**	**TDS (ppm)**	**Volume (AF)**	**TDS (ppm)**	**TONS**	**Percent**
Rainfall	12,868	0	12,868	0	0	0%
Natural Stream Recharge	11,492	367	11,492	367	5,720	46%
Artificial Recharge	2,683	170	2,683	170	620	5%
Urban Irrigation	9,382	319	1,048	2,851	4,060	33%
Agriculture Irrigation	1,320	195	303	848	350	3%
Subsurface Inflow	810	1,500	810	1,500	1,650	13%
TOTAL	**38,555**		**29,204**		**12,400**	

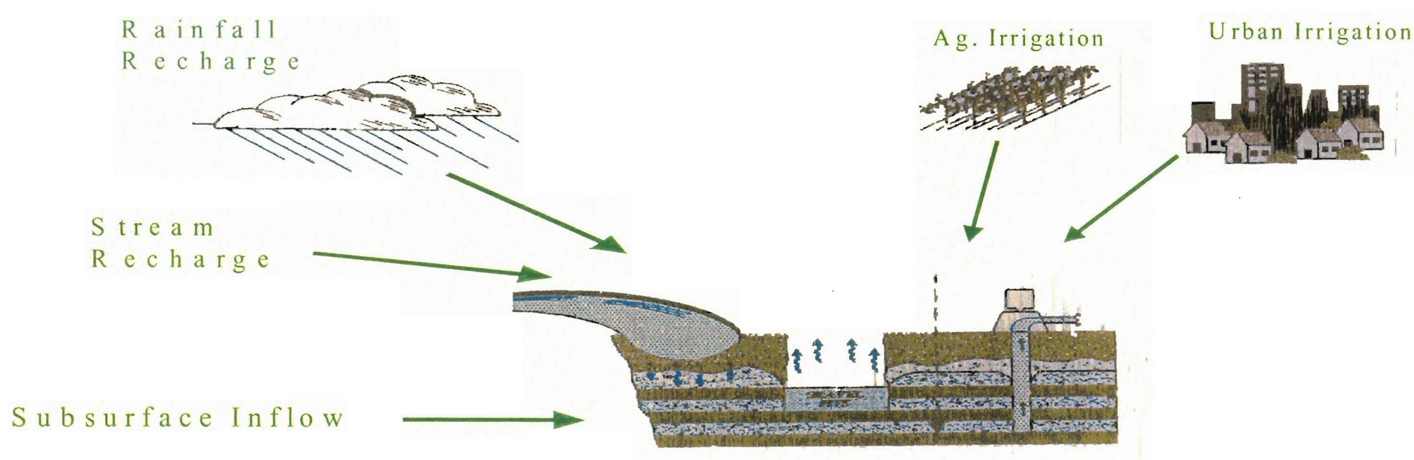


Figure 5.1

1998 Groundwater Main Basin Salt Removal

Removal Component	Volume (AF)	TDS (ppm)	Salt Removed Tons	Salt Removed Percent
Municipal Pumpage	10,267	470	6,510	38%
Agricultural Pumpage	108	470	70	0%
Mining Expot/Offhaul	13,317	530	9,580	56%
Mining pond Evaporation	925	0	0	0%
Subsurface Outflow	750	980	1,000	6%
TOTAL	**25,367**		**17,160**	

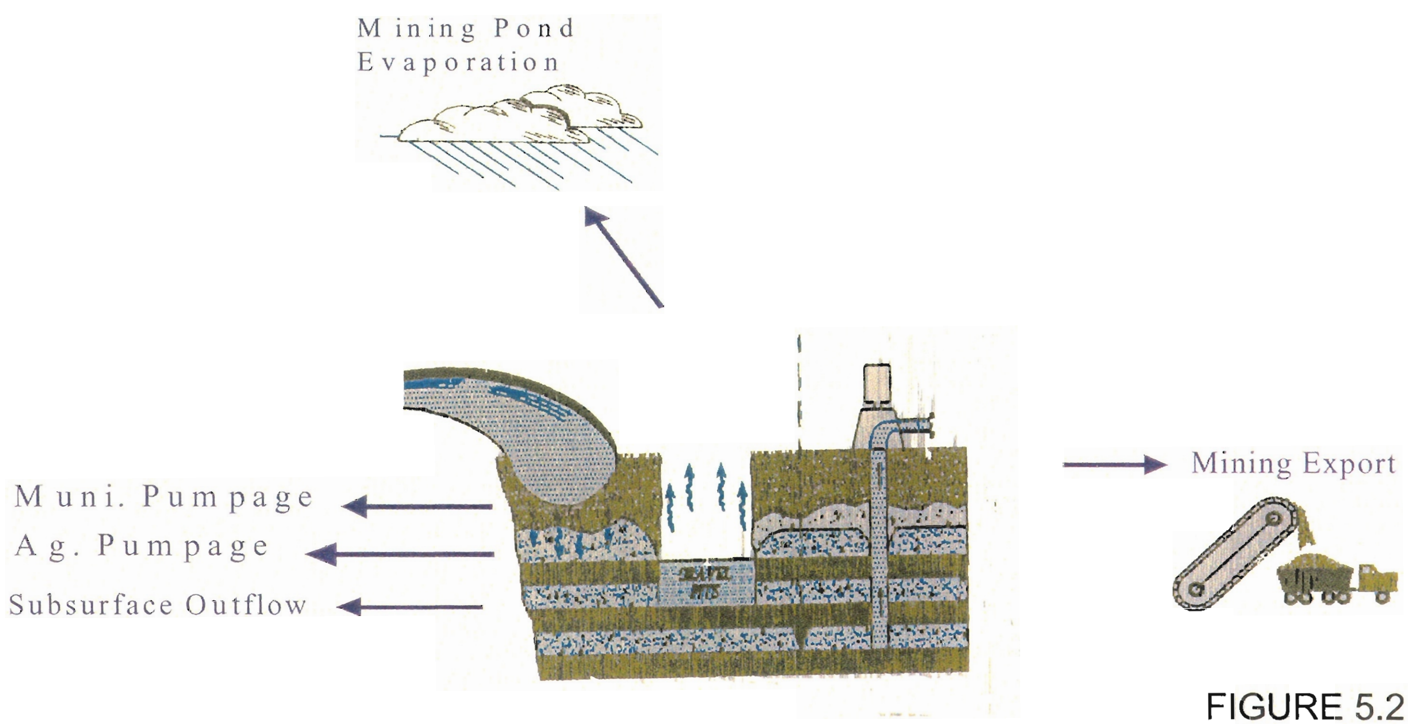
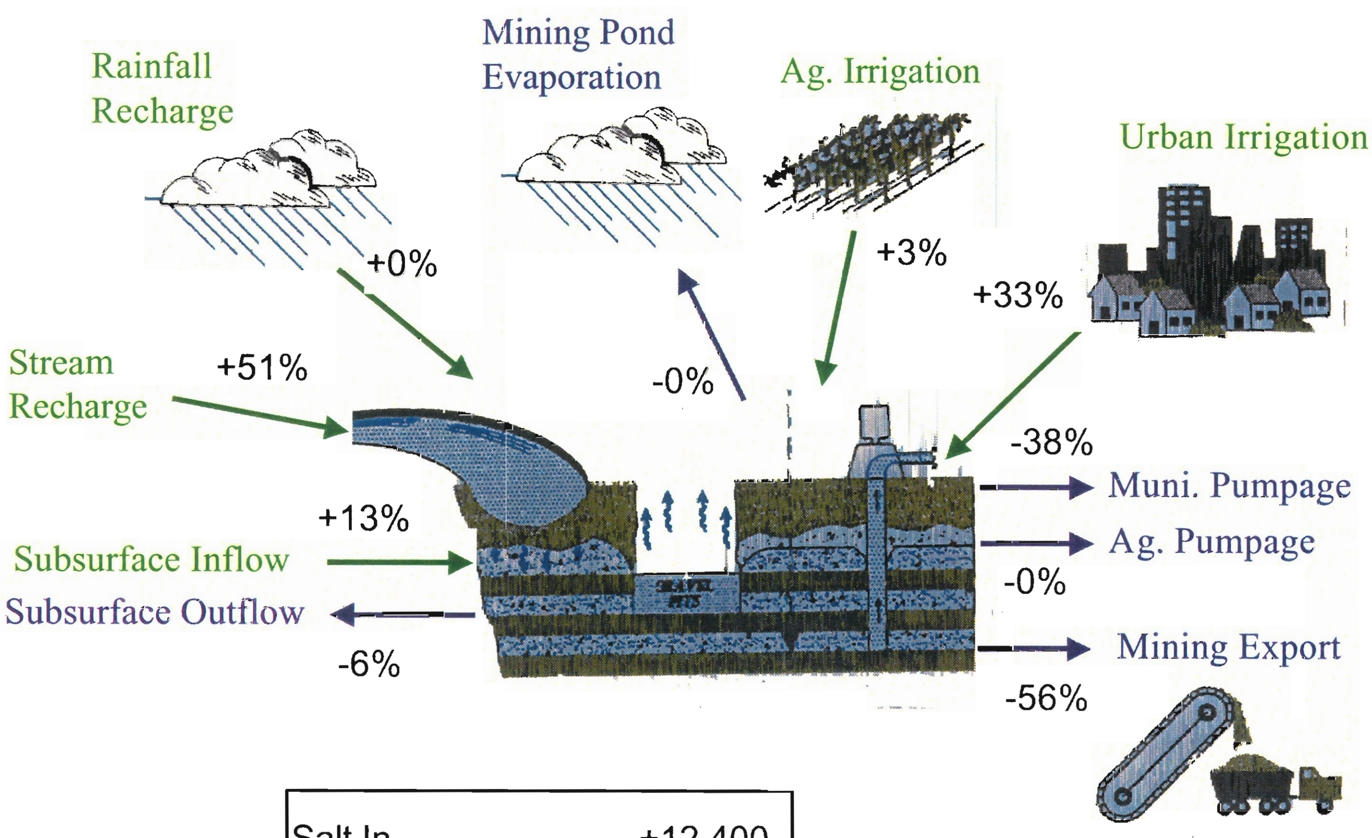


FIGURE 5.2

Main Basin Salt Balance
1998 Water Year Net Salt Loading



Salt In	+12,400
Salt Out	-17,160
Net Salt Load (In Tons)	-4,760

Figure 5.3

loading is determined. A parallel series of three figures is presented in the following section 5.5 showing results under calculated steady state conditions to illustrate the significant differences that can occur between a given (e.g., wet) year and long-term average conditions.

Figure 5.1 shows the major sources of salt loading: rainfall, natural stream recharge, artificial recharge, urban irrigation, agricultural irrigation, and subsurface inflow. The recharge values are generally more informative than the applied values since they reflect the quality and quantity of water actually entering the Main Basin (versus applied at the ground surface). The 12,868 AF of rainfall recharge (with zero TDS) was a very significant contributor to the total recharge in the Main Basin and the favorable salt balance for the year. Natural stream recharge of 11,492 AF was the next most significant contributor to recharge in the Main Basin (39% of total volume) with an average TDS of 370 mg/L and a salt load of 5720 tons (46% of total salt load).

Since the basin was near the top of managed storage levels, the reduced artificial recharge (stream & ASR) program contributed only 2,683 AF (9%) at an average TDS of 170 mg/L and a salt load of 620 tons (5% of total salt). Urban irrigation contributed 1,048 AF (3.5%) to the Main Basin recharge but had the highest average TDS by a factor of two at 2,850 mg/L and contributed 4,060 tons (33% of total salt). Agriculture irrigation contributed 303 AF (1%) to the Main Basin recharge at an average TDS of 848 mg/L with 350 tons (3% of total salt). Subsurface inflow contributed 810 AF (2.7%) to the recharge at an average TDS of 1,500 mg/L with 1,650 tons (13% of total salt).

Figure 5.2 presents a summary of groundwater demand and salt removal components for the 1998 water year. Municipal pumpage and water export by gravel mining companies were the two dominant components. Municipal groundwater demand was 10,267 AF (40% of total volume) at an average TDS of 470 mg/L and removed 6,510 tons (38%) of salt. Groundwater export by gravel mining companies exported 13,317 AF (52%) at 530 mg/L with 9,580 tons (55%) of salt. Water and salt export by agricultural irrigation was negligible. Subsurface outflow was 750 AF (3%) at 980 mg/L with 1,000 tons (6%) of salts.

Figure 5.3 summarizes the net salt loading to the Main Basin during water year 1998. Total salt loading was 12,400 tons, and a total of 17,160 tons of salt were removed, for a net removal of 4,760 tons. This significant net removal (compared to the steady state increase of 2,200 tons/year) is due to both lower salt inputs and greater exports (see Figure 5.6). Stream recharge and urban irrigation were the major salt contributors at 48% and 35% respectively. Mining export and municipal pumpage were the major removal mechanisms at 49% and 46%, respectively.

5.5 Steady State Results at 1998 Land Use Conditions

This section presents the steady state salt balance calculation results under current (1998) land use conditions. As discussed in Section 5.2, these steady state calculations are more useful for tracking long-term expected TDS impacts on the basin than actual year-to-year salt balances. Detailed supply, demand and individual component loading results are presented in Table 5.2 and in Figures 5.4 –5.6 (same format as for actual 1998 results).

Figure 5.4 presents a summary of the recharge water supply and salt loading components at steady state conditions and under 1998 land use conditions. The major contributors to gross salt loading are urban irrigation, natural stream recharge, and artificial stream recharge at 35%, 30%, and 18% respectively of the total loading. Of these, only urban irrigation is considered potentially "controllable." Natural recharge is a function of rainfall and artificial recharge is necessary to offset groundwater extractions and keep the basin full.

The 4,100 AF of rainfall recharge at zero TDS is a significant contributor to the total recharge of 22,050 AF. As expected for average weather conditions, it is about one-third the rainfall recharge experienced in the unusually wet 1998 (Figure 5.1). Under these steady state conditions, natural stream recharge would contribute 6,600 AF, (30% of the recharge volume) to the Main Basin with an average TDS of 530 mg/L and a salt load of 4,750 tons (30% of the total salt load). The artificial recharge program would contribute 8,500 AF (39%) at an average TDS of 250 mg/L with 2,890 tons (18%) of salt. Urban irrigation would contribute 1460 AF (6.6%) to the Main Basin recharge at the highest average TDS of 2780 mg/L and 5520 tons (35%) of salt. Agriculture irrigation would contribute 390 AF (1.7%) to the Main Basin recharge at TDS of 1,090 mg/L with 580 tons (4%) of salt. Subsurface inflow would contribute 810 AF (2.7%) to the recharge at 1,500 mg/L with 2,040 tons (13%) of salt.

Figure 5.5 presents a summary of groundwater demand and salt removal components for the 1998 steady state conditions. Municipal pumpage and water export by gravel mining companies represent by far the two largest components of water and salt export. Municipal groundwater demand would be 10,220 AF (46% of total groundwater pumpage) at an average TDS of 450 mg/L and it would remove 6,240 tons (46%) of salt. Groundwater export by gravel mining companies would export 9,400 AF (43%) at 520 mg/L with 6,640 tons (49%) of salt. Evaporation from the mining pond would remove about 1,700 AF (8%) at zero TDS. Salt export by agriculture irrigation over the Main Basin would be about 1% of the total. Subsurface outflow would be 500 AF (2%) at 900 mg/L with 610 tons (4%) of salt.

Figure 5.6 schematically presents the major salt percentage contributions to and extractions from the main groundwater basin under 1998 steady state conditions. The major input difference when compared to actual 1998 values (Figure 5.3) is that the stream recharge contribution is lower. Removals via municipal pumpage are higher and by mining export lower under these more typical steady state conditions. The total salt

TABLE 5.2

Main Basin Water Balance and Salt Balance
Current Steady State Conditions at 1998 Land use

WATER SUPPLY COMPONENTS	APPLIED WATER		RECHARGE WATER		SALT LOAD	SALT LOAD IN TONS PER 1000 ACRE-FOOT OF RECHARGE
	ACRE-FEET	TDS IN mg/l	ACRE-FEET	TDS IN mg/l	IN TONS	
NATURAL						
Rainfall recharge water			4,100	0	0	
Arroyo Valle:						
Lake/imported water recharge	1,000	250	1,000	250	340	340
Natural recharge	1,700	440	1,700	440	1,016	600
Total Arroyo Valle	2,700		2,700		1,356	500
Arroyo Mocho natural recharge	2,700	480	2,700	480	1,761	650
Arroyo las Positas natural recharge	1,200	1,000	1,200	1,000	1,630	1,360
Urban Irrigation						
SBA urban irrigation	8,830	250	970	2,276	2,999	3,090
Groundwater						
Zone 7 Groundwater, extraction only wells (NO RO)	640	450	70	4,114	391	5,590
Zone 7 Groundwater, extraction only wells (RO)	0		0		0	
Zone 7 Groundwater, ASR wells	0	300	0		0	0
Groundwater, others (no RO)	2,830	450	310	4,108	1,730	5,580
Domestic groundwater pumpage	70	450	70	450	43	610
LWRP reclaimed water irrigation	400	650	40	6,500	353	8,830
Total Urban Irrigation	12,770		1,460	17,448	5,516	
Agricultural Irrigation						
SBA water	1,350	250	340	993	458	1,350
Groundwater agricultural irrigation	200	450	50	1,800	122	2,440
Total agricultural irrigation	1,550		390	2,793	580	
Subsurface groundwater inflow	1,000	1,500	1,000	1,500	2,038	2,040
Total Natural Supply	21,920		13,550		12,881	950
ARTIFICIAL RECHARGE						
Stream Recharge						
Arroyo Valle	0		0		0	
Arroyo Mocho	7,000	250	7,000	250	2,377	340
Injection Well Recharge	1,500	250	1,500	250	509	340
RO Recycled Water Injection / Stream Recharge	0	100	0	100	0	0
RO Recycled Water Irrigation	0	100	0	100	0	0
TOTAL SUPPLY	30,420	380	22,050	530	15,767	

WATER DEMAND COMPONENTS	WATER REMOVED		SALT LOAD	SALT REMOVED IN TONS PER 1000 ACRE-FOOT OF EXPORT
	ACRE-FEET	TDS IN mg/l	IN TONS	
Municipal Pumpage				
Zone 7 municipal pumpage, ASR wells	0	300	0	0
Zone 7 municipal pumpage, extraction only wells	2,000	450	1,220	610
Other municipal pumpage	8,220	450	5,020	610
Total municipal pumpage	10,220		6,240	610
Agricultural pumpage	200	450	120	600
Mining export	8,700	520	6,150	710
Mining offhaul	700	520	490	700
Pond evaporation	1,700	0	0	0
Subsurface groundwater outflow	500	900	610	1,220
Total Demand	22,020	450	13,610	
WATER/SALT BALANCE	**0**		**2,160**	

Main Basin Salt Load
Steady State Conditions at 1998 Land Use

	Applied Water		Recharge Water		Salt Load	
Salt source	**Volume (AF)**	**TDS (ppm)**	**Volume (AF)**	**TDS (ppm)**	**TONS**	**Percent**
Rainfall	4,100	0	4,100	0	0	0%
Natural Stream Recharge	6,600	530	6,600	530	4,750	30%
Artificial Recharge	8,500	250	8,500	250	2,890	18%
Urban Irrigation	12,770	320	1,460	2,780	5,520	35%
Agriculture Irrigation	1,550	280	390	1,090	580	4%
Subsurface Inflow	1,000	1,500	1,000	1,500	2,040	13%
TOTAL	**34,520**		**22,050**		**15,780**	

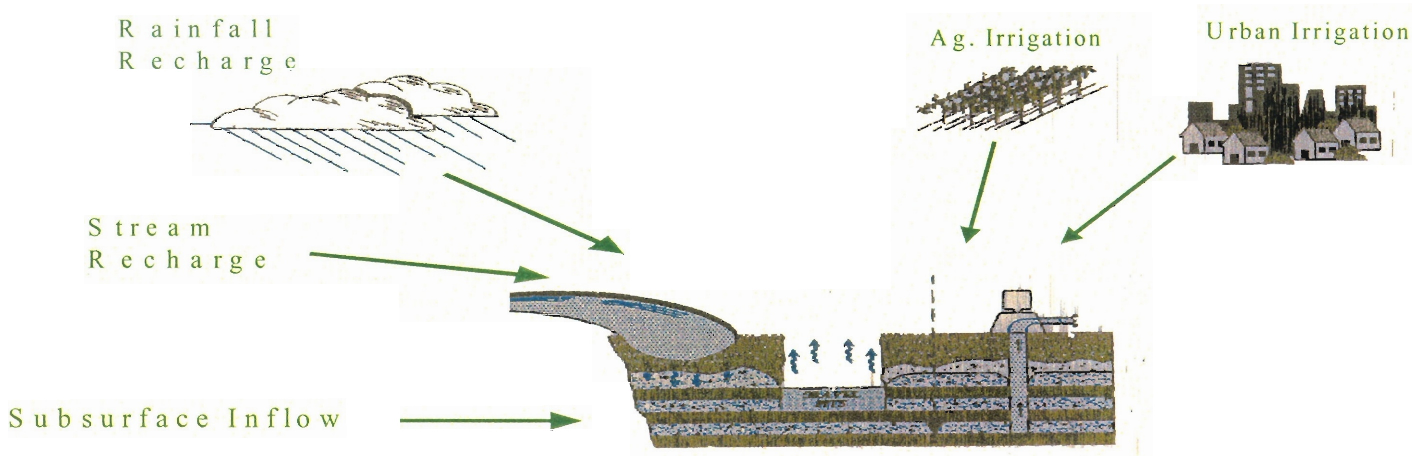


Figure 5.4

Main Basin Salt Removal

Steady State Conditions at 1998 Land Use

Removal Component	Volume (AF)	TDS (ppm)	Salt Removed Tons	Salt Removed Percent
Municipal Pumpage	10,220	450	6,240	46%
Agricultural Pumpage	200	450	120	1%
Mining Expot/Offhaul	9,400	520	6,640	49%
Mining pond Evaporation	1,700	0	0	0%
Subsurface Outflow	500	900	610	4%
TOTAL	**22,020**		**13,610**	

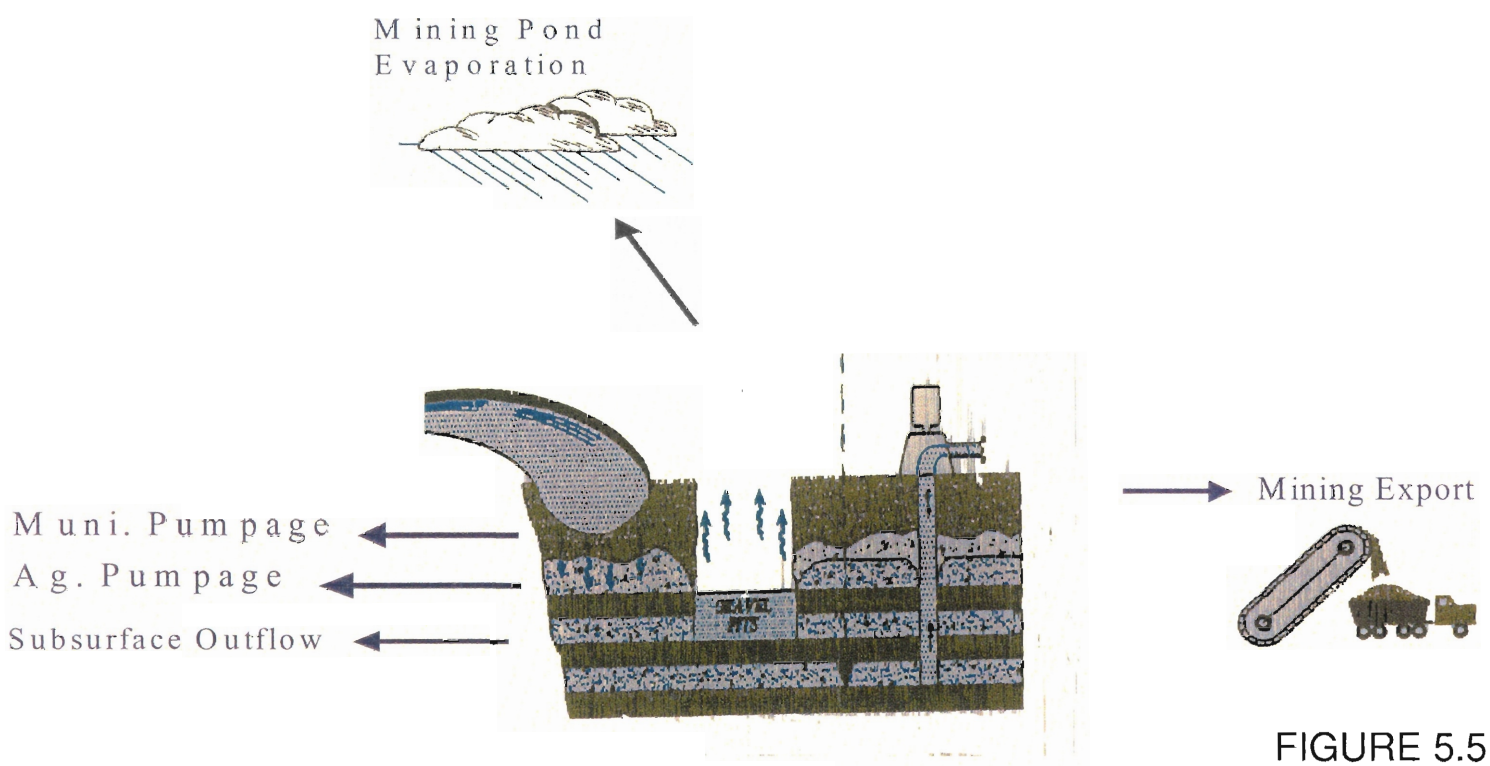
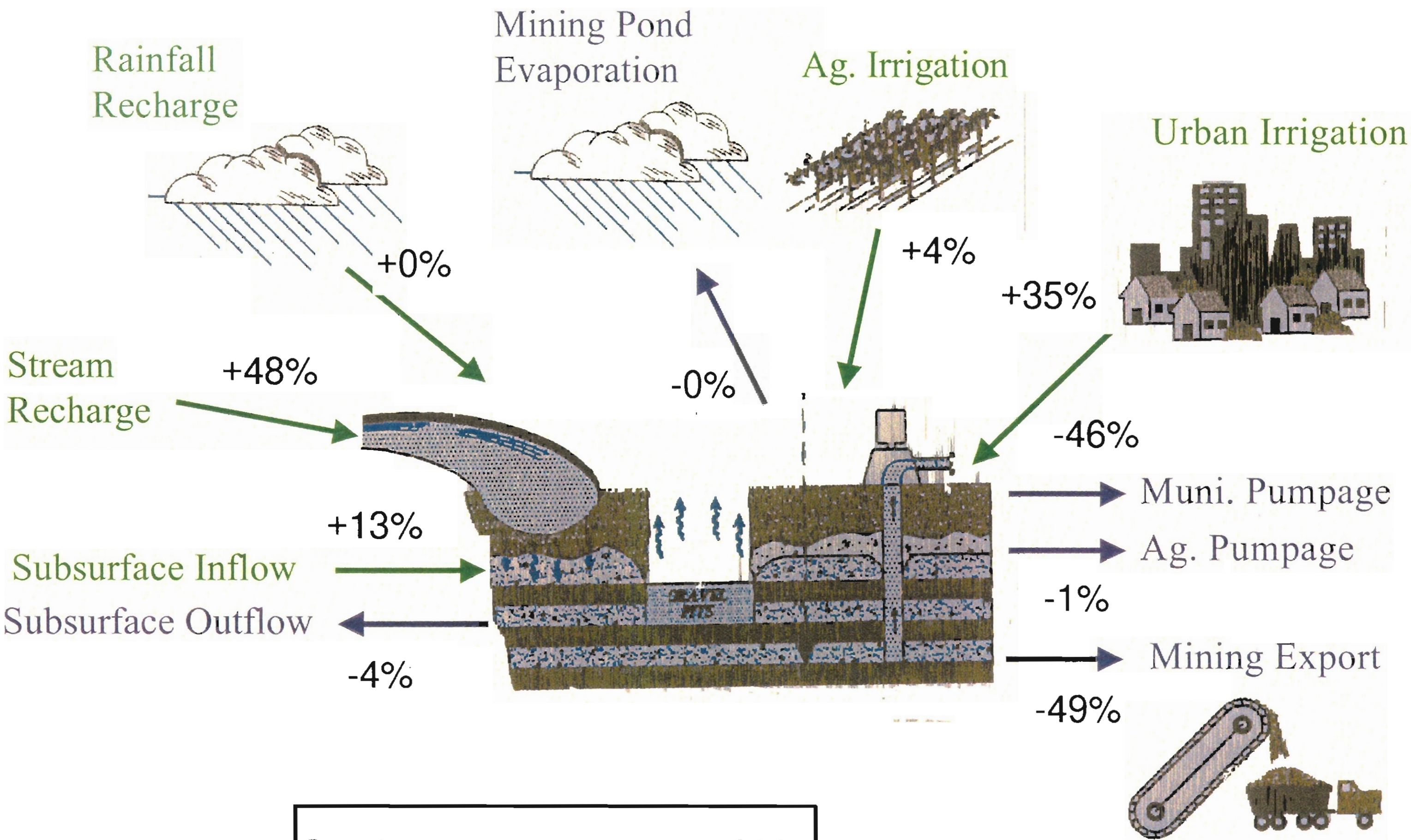


FIGURE 5.5

Main Basin Salt Balance
Steady State Conditions at 1998 Land Use



Salt In	+ 15,800
Salt Out	-13,600
Net Salt Load (In Tons)	+ 22,00

Figure 5.6

loading to the Main Basin would be 15,800 tons and the total salt removal would be 13,600 tons, for a net salt loading of 2,200 tons. These steady state results are the basis for the 2,200 tons/year net salt loading used in this Salt Management Plan to define current salt loading. As discussed above relative to 1998 actual data and as shown in the historic annual average loadings presented below (Figure 5.7), year-to-year loadings can vary considerably.

5.6 Historic Annual Average Salt Loading

A summary of the annually calculated salt loadings and associated cumulative salt loading to the Main Basin for the 25-year hydrologic inventory period, 1974 through 1998 is presented in Figure 5.7. Annual net loadings varied from 11,781 to a negative 4,760 tons, with a 25-year average of about 2,550 tons/year, which is interestingly fairly close to the 1998 steady state value of 2,200 tons/year. The cumulative salt loading to the Main Basin during that time period was approximately 63,500 tons and there were only six years in which there was a negative salt accumulation in the Main Basin, three of them being 1996-1998.

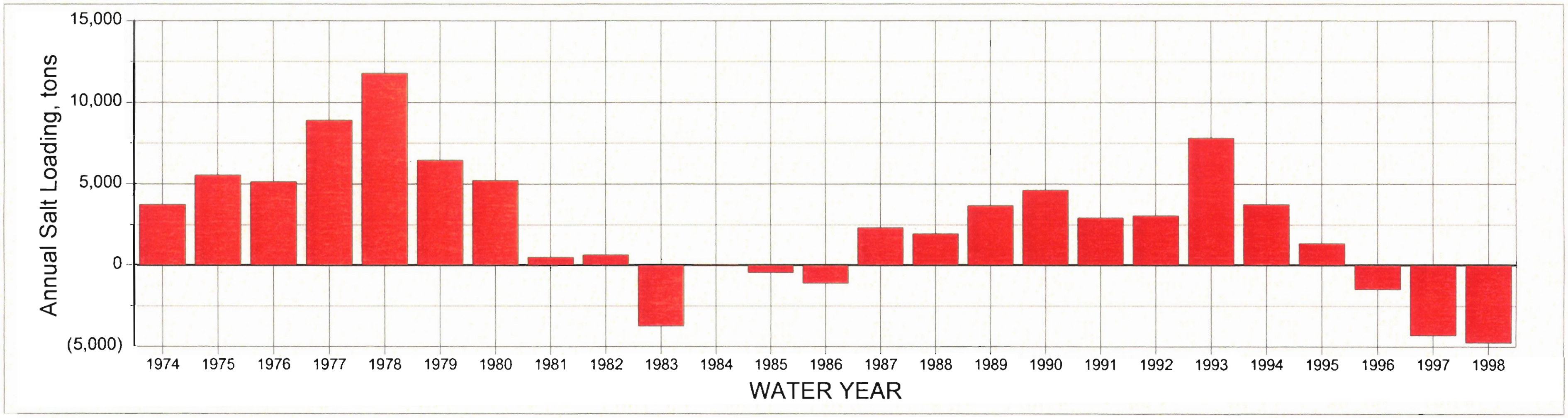
The complete 25-year dataset can be found in Reference J, Tables 3A, 3B, and 3C. Review of that complete dataset helps understand the multiple and sometimes independent factors influencing the observed annual variability. For example, part of the reason for the elevated loadings during 1974-1980 was the treated wastewater discharges that terminated with start-up of the LAVWMA export pipeline in 1980. Mining exports were also relatively low in this period as the gravel companies were mining in the shallower zone gravel areas.

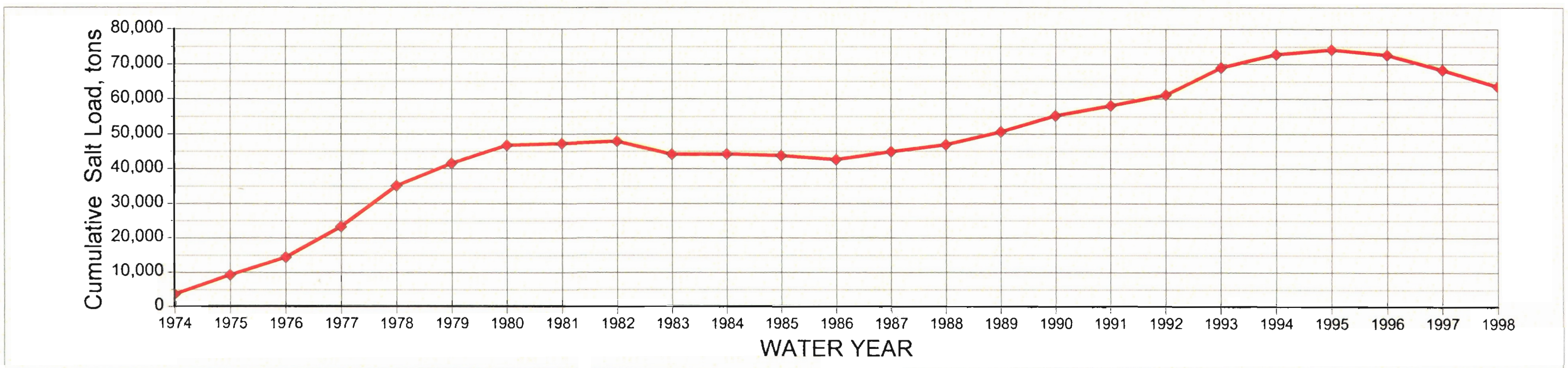
The highest net loading of 11,781 tons occurred in 1978 when significant natural and artificial recharge began to refill the basin and mining exports remained low following the 1976-1977 drought. The large negative loading in 1983 occurred when the basin had been refilled to an elevation of 240 feet resulting in significant mining export and the highest subsurface basin outflow. The increased loadings during 1987-1992 were due to drought conditions when basin groundwater elevations dropped. Mining exports therefore decreased considerably, urban irrigation loading increased due to the greater percentage of groundwater used, and subsurface inflow increased due to the lower basin elevations. The peak of 7,820 tons in 1993, a wet year, was primarily due to considerable natural and artificial recharge and reduced municipal pumpage. The low and negative loadings in 1995-1998 were primarily due to high rainfall and recharge, increased mining export and subsurface outflow, and also increased municipal pumping.

Figure 5.8 shows the theoretical effect of the above cumulative mass salt loading on the TDS concentration in the Main Basin. The cumulative impact graph is calculated assuming a beginning groundwater basin storage volume of 212,000 AF and an initial TDS of 450 mg/L. Subsequent end-of-year TDS values are the result of changes in the net recharge and the salt influx for that year. Yearly values are calculated using the cumulative

Figure 5.7

LIVERMORE - AMADOR VALLEY MAIN GROUNDWATER BASIN
1974 - 98 SALT LOADING

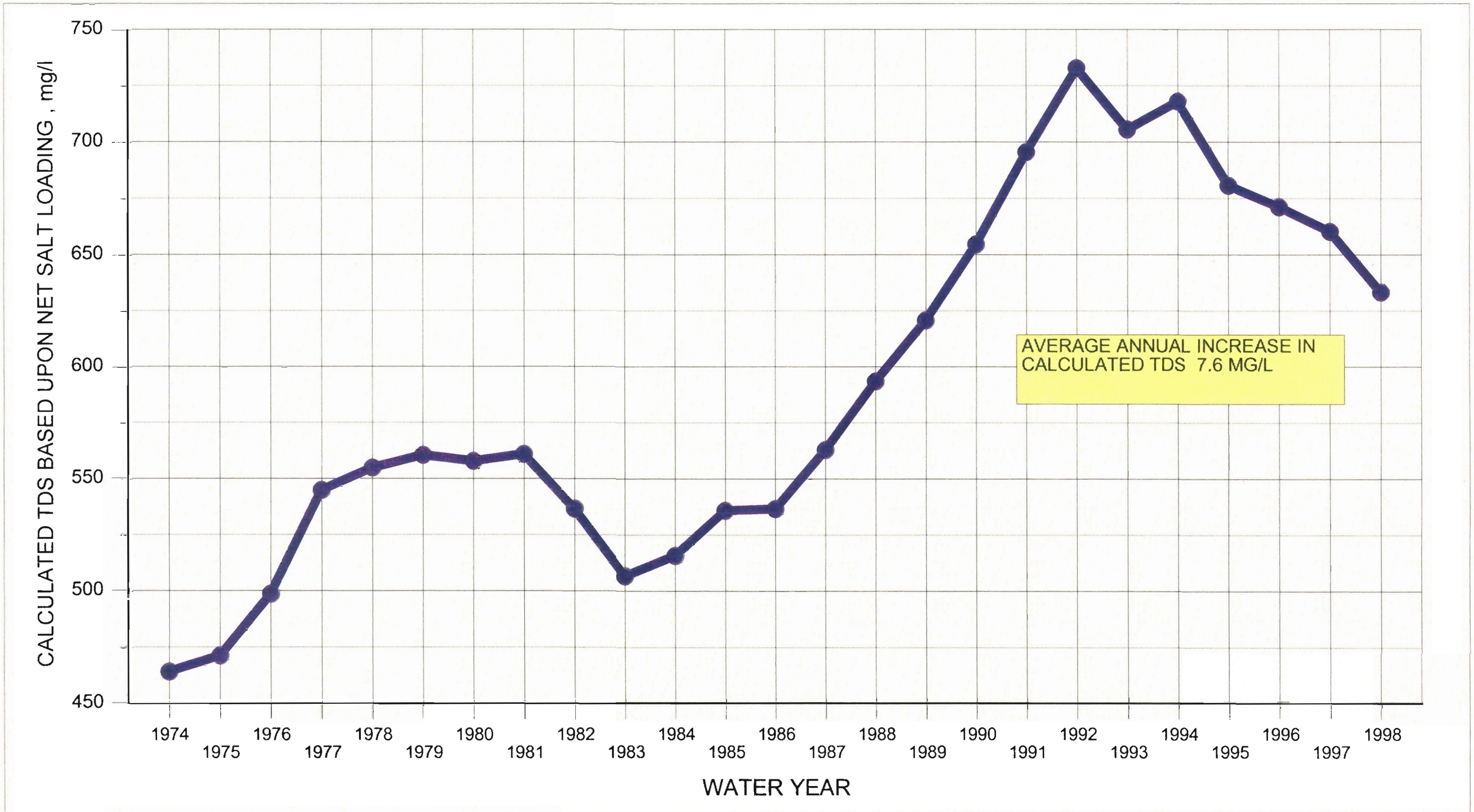




SALT_INV.123

FIGURE 5.8

LIVERMORE - AMADOR VALLEY MAIN GROUNDWATER BASIN
CALCULATED BASIN TDS DUE TO SALT LOADING AT LAND SURFACE



mass loading through that year (since 1974) divided by the actual end-of-year storage volume existing for that year.

The cumulative salt loading from 1974 through 1998, given the assumptions of 100% mixing and negligible permanent vadose zone attenuation, would result as shown in Figure 5.8 in an average basin TDS of 635 mg/L in 1998. This is equivalent to a total increase of about 183 mg/L over the 25-year period, equal to about a 7.3 mg/L increase per year or about a 1.5% increase per year over the initial 450 mg/L.

This graph is a highly simplified representation of the relative changes in groundwater basin quality actually occurring due to the addition or reduction of salts since it assumes rapid, complete, and uniform mixing throughout the basin. It also assumes complete mixing between both shallow and deep aquifers. Shallow groundwater in many areas has higher TDS than the underlying deep aquifer due to high TDS irrigation recharge and in some cases historic high TDS soils or deposits. In actuality, the existence and relative thickness of clay soils in certain areas may greatly retard the salts applied from irrigation in moving through the vadose zone, reaching, and completely mixing with the Main Basin aquifers.

Other factors can also affect the actual TDS change occurring in a given portion of the basin as measured at a given well. These include individual well depth, proximity and capacity of adjacent wells, amount and timing of pumping and recharge, time of sampling, source of recharge water, and as for any measurement, sampling technique. Given these variables, the cumulative salt loading based TDS concentration estimates should, therefore, be viewed as an indicator of the relative magnitude of overall potential TDS change in the Main Basin and not necessarily as representative of site specific changes.

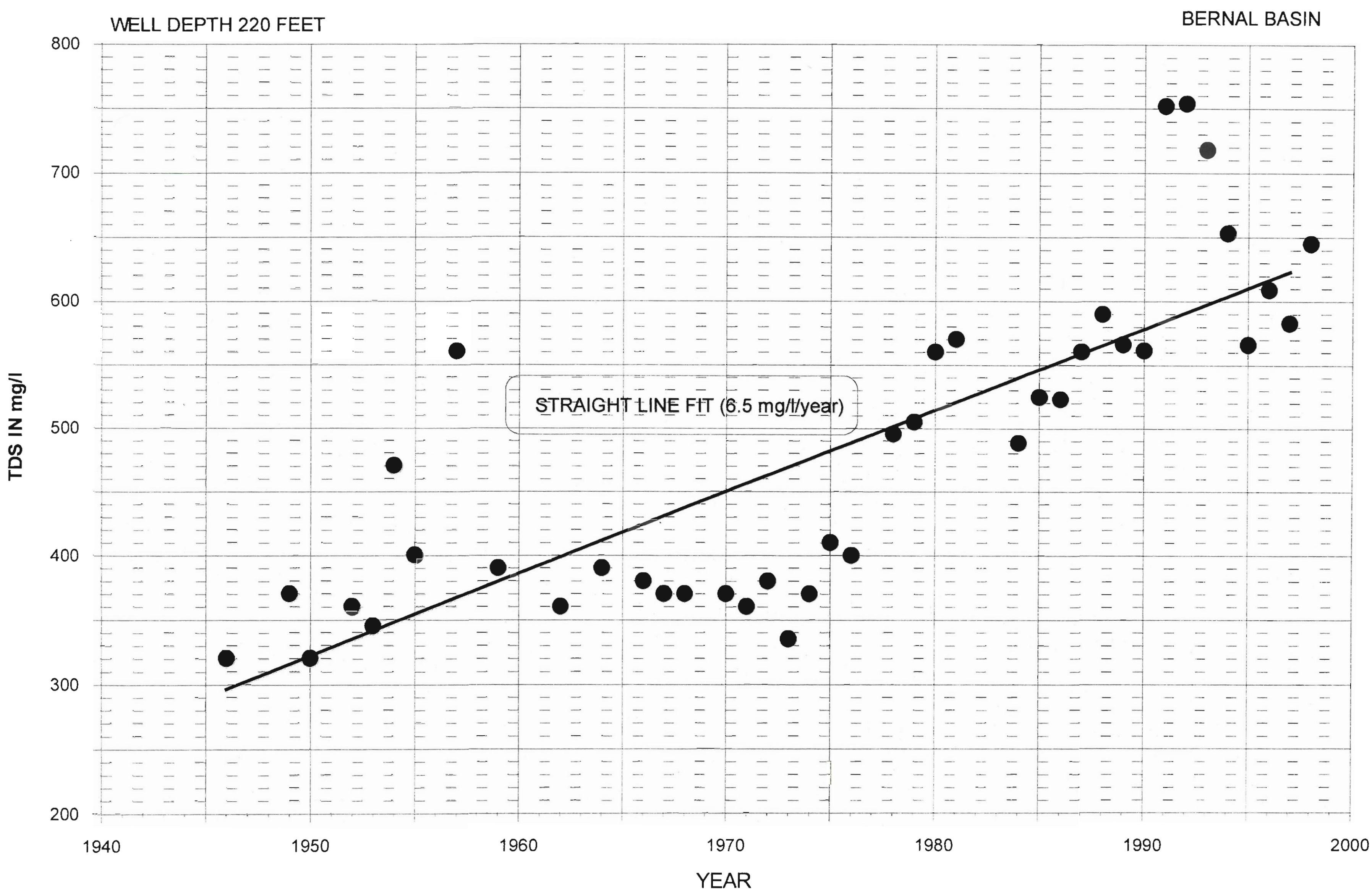
Actual monitoring results from two wells in widely different areas of the basin are presented (figures 5.9 & 5.10) to bracket the range of TDS variability existing due to some of these factors and the heterogeneity of the basin. While the respective rates of TDS increase vary, both wells show a continuing upward trend in TDS.

Figure 5.9 presents measured groundwater TDS data from San Francisco Water Department (SFWD) wells pumping into a common header from a depth of 220 feet in the central portion of the Bernal sub-basin. The wells deliver about 400 AF per year to serve the Castlewood residential community. Measured TDS values ranged from near 300 mg/L in 1950 to the 650 mg/L range in the 1990's. A cluster of values above 700 mg/L in the early 1990's may not be representative due to sampling problems (e.g., not allowing sufficient purging prior to collecting samples). A straight line regression fit to the data indicates an increase of 6.5 mg/L per year, fairly close to the 7.6 mg/L per year derived from the salt loading based basin-wide data shown in Figure 5.8.

This southwestern portion of the Main Basin is not pumped heavily and is believed to be primarily influenced by salts from local irrigation and rainfall recharge. There are areas of high TDS shallow groundwater in the vicinity that could migrate downward faster if the

Figure 5.9

GROUNDWATER TDS FROM SFWD O-LINE

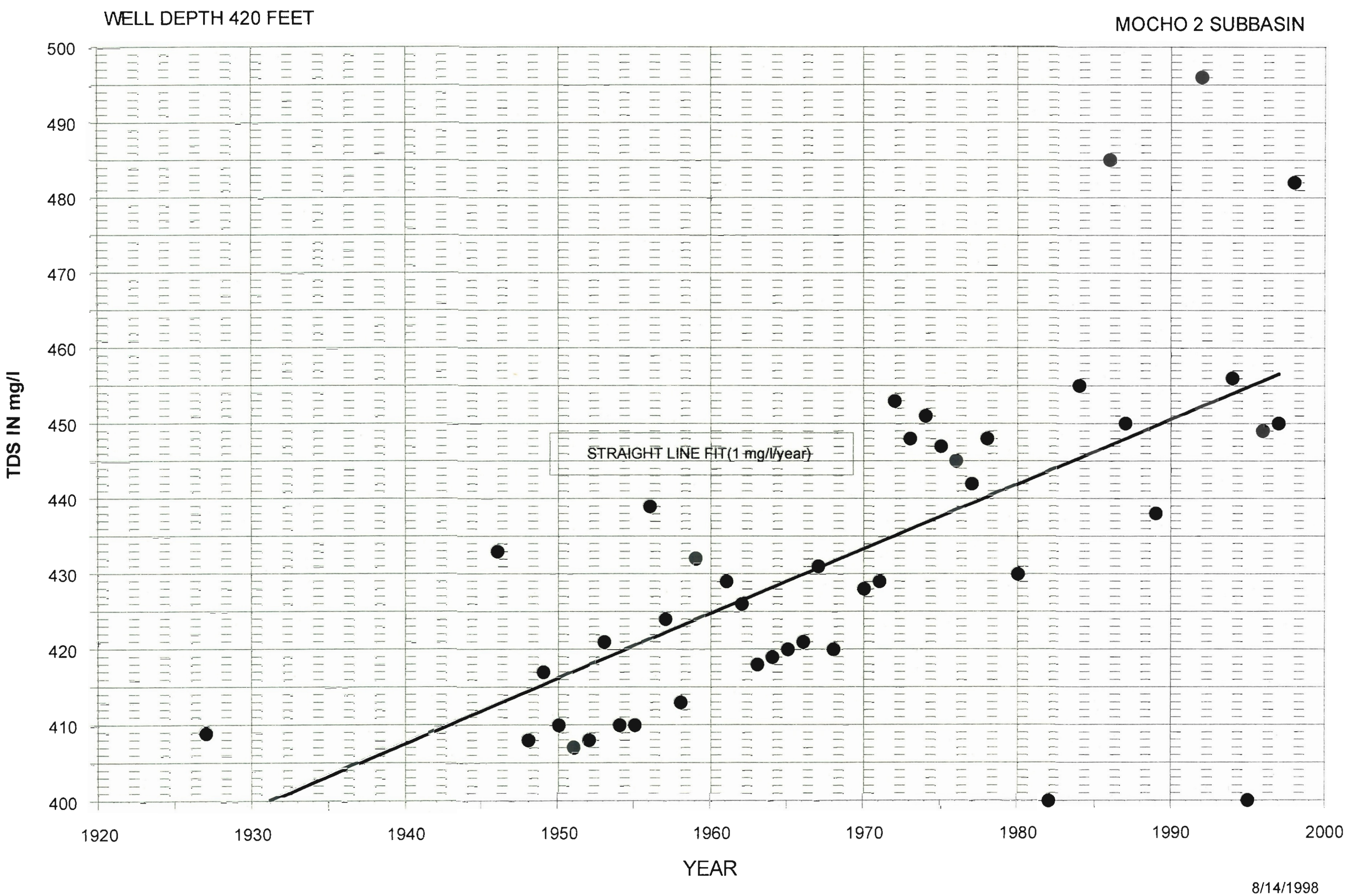


NOTE: ALL DATA IS FROM O-LINE (DEEP AND SHALLOW WELLS)

8/14/98

Figure 5.10

GROUNDWATER TDS FROM WELL 3S/2E 8P2 (CWS#03)



basin elevation were to be lowered significantly (in a drought). The Bernal subbasin is also believed to be influenced somewhat by the low TDS recharge on Arroyo Mocho and by high TDS subsurface inflow from the north.

In contrast to the above SFWD well, Figure 5.10 presents measured data from a California Water Service (CWS) deep well located in the eastern portion of the Mocho II subbasin at a depth of 420 feet. This well also has a capacity of about 400 AF per year. TDS values range from just over 400 mg/L in 1950 to around 450 mg/L in the mid-1990's. Sampling inconsistencies similar to the SFWD well may account for some of the unusually high and low data points observed since 1980. A straight line regression fit to the data shows an average TDS increase of about 1 mg/L per year. This well is significantly influenced by the large amount of low TDS natural and artificial recharge that occurs in the nearby Arroyo Mocho.

5.7 Projected Year 2010 Salt Loading

The "spreadsheet model" used for these salt balance calculations is useful for providing annual estimates of the basin-wide salt inventory and estimating potential long-term impacts on average groundwater TDS concentrations. As discussed in Section 3.7, Zone 7 developed a groundwater and solute transport computer model for the basin to be able to evaluate the more detailed impacts on individual areas and wells within the Main Basin.

The salt balance results presented in this chapter demonstrate that cumulative salt loading and groundwater TDS will continue to increase unless measures are taken to offset the current 2,200 tons/year salt loading and additional increases due to likely future development. To begin the process of evaluating potential salt management strategies, Zone 7 used this steady state methodology to identify that the magnitude of salt loading to the Main Basin might be by the year 2010 if no changes were made in Zone 7 basin management practices.

The salt loading impacts under steady state conditions at year 2010 land use conditions and under historic Zone 7 operations (Status Quo) are shown in Table 5.3 and Figure 5.11. The results show that in 2010 the average net salt loading would increase by approximately by 3,200 tons to 5,400 tons per year. The increase from 2,200 tons under 1998 land use conditions to 5,400 tons under 2010 conditions is due primarily to the cessation of water and salt export by the gravel mining companies. The lack of gravel mining exports alone will increase 2010 loading by about 2,700 tons per year. Recent information indicates that the GW export due to mining operations will cease as soon as 2003. The increase in 2010 loading over 1998 due to planned urban and agricultural development and associated irrigation (land use data from CDM *November 1996* Water and Land Use Memorandum) was predicted to be about *500 tons* per year. Table 5.4 presents the major differences in water supply, land use, and salt loading between 1998 and 2010 conditions.

STUDY 1A

TABLE 5.3

Main Basin Water Balance and Salt Balance
2010 Steady State Conditions

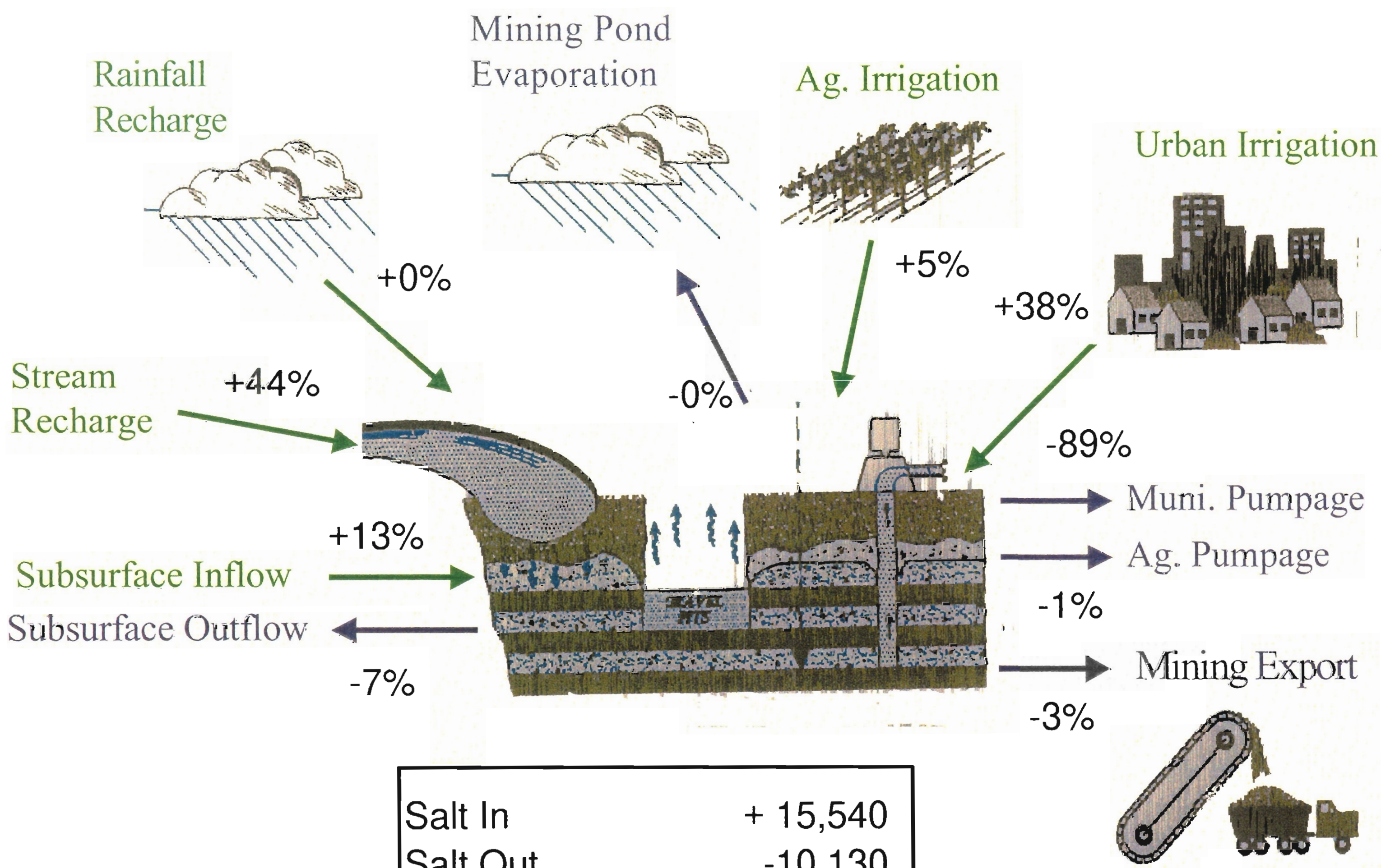
WITH NO ATTENUATION OF SALTS IN APPLIED WATER AND NO CONJUNCTIVE USE PUMPAGE FOR SALT MITIGATION
NO RECYCLED WATER INJECTION

WATER SUPPLY COMPONENTS	APPLIED WATER		RECHARGE WATER		SALT LOAD IN TONS	SALT LOAD IN TONS PER 1,000 ACRE-FEET OF RECHARGE
	ACRE-FEET	TDS IN mg/l	ACRE-FEET	TDS IN mg/l		
NATURAL						
Rainfall recharge water			4,100	0	0	
Arroyo Valle:						
Lake/imported water recharge	1,240	250	1,240	250	420	340
Natural recharge	1,830	440	1,830	440	1,090	600
Total Arroyo Valle	3,070		3,070		1,510	
Arroyo Mocho natural recharge	2,610	480	2,610	480	1,700	650
Arroyo las Positas natural recharge	1,260	1,000	1,260	1,000	1,710	1,360
Urban Irrigation						
SBA water	9,440	250	880	2,682	3,210	3,650
Groundwater, Extraction only wells	3,370	450	310	4,892	2,060	6,650
Groundwater, ASR wells	600	250	60	2,500	200	3,330
Domestic groundwater pumpage	120	450	70	771	70	1,000
LWRP reclaimed water irrigation	405	650	40	6,581	360	9,000
Total Urban Irrigation	13,935		1,360		5,900	4,340
Agricultural Irrigation						
SBA water	1,740	250	440	989	590	1,340
Groundwater	200	450	50	1,800	120	2,400
Total agricultural irrigation	1,940		490		710	1,450
Subsurface groundwater inflow	980	1,500	980	1,500	2,000	2,040
Total Natural Supply	23,795		13,870		13,530	980
ARTIFICIAL RECHARGE						
Stream recharge	3,540	250	3,540	250	1,200	340
Injection well recherge (ASR wells))	2,390	250	2,390	250	810	340
Recycled water injection	0	100	0		0	0
Recycled water irrigation	0	0	0		0	0
TOTAL SUPPLY	29,725		19,800		15,540	

WATER DEMAND COMPONENTS	WATER REMOVED		SALT LOAD IN TONS	SALT REMOVED IN TONS PER 1,000 ACRE-FEET OF EXPORT
	ACRE-FEET	TDS IN mg/l		
Municipal Pumpage				
Zone 7 municipal pumpage, ASR pumpage	2,390	250	810	340
Zone 7 municipal pumpage, Extraction only wells	5,110	450	3,130	610
Conjunctive use pumpage, Extraction only wells	0	450	0	0
Pumpage for injected recycled water, Extraction only wells	0	450	0	0
Other municipal pumpage	8,300	450	5,080	610
Total municipal pumpage	15,800		9,020	570
Agricultural pumpage	200	450	120	600
Mining export	0	520	0	0
Mining offhaul	400	500	270	680
Pond evaporation	2,800	0	0	0
Subsurface groundwater outflow	590	900	720	1,220
Total Demand	19,790		10,130	

WATER/SALT BALANCE	**10**	**5,410**

Main Basin Salt Balance
2010 Water Year Net Salt Loading



Salt In	+ 15,540
Salt Out	-10,130
Net Salt Load (In Tons)	+ 5,410

Figure 5.11

The 2010 5,400 tons per year salt loading does not include potential future salt loading from new or retrofit recycled water irrigation projects (as has been recently proposed as part of vision 2010 North Livermore Plan), greatly increased irrigated agriculture (viticulture), or significantly increased loading from the fringe basins. For the purpose of these analyses, land use changes above the fringe basins or otherwise outside the Main Basin are assumed to have no impact on salt loading to the Main Basin. Most new development is occurring in these areas, hence the relatively modest increases shown in 2010 salt loading for urban and agricultural irrigation. It is known that over a period of decades, new or increased irrigation in certain portions of the fringe basins may result in some incremental salt loading reaching the Main Basin.

Table 5. 4
Main Basin Salt Loading Major Changes

	Units	1998	2010	Change
Salt Loading				
Urban Over the Main Basin				
Area	Acres	8700	10030	1330
Irrigation	AF	12770	13940	1170
Salt load	Tons	5520	5900	380
Agricultural Over the Main Basin				
Area	Acres	900	1200	300
Irrigation	AF	1550	1940	390
Salt load	Tons	580	710	130
Salt Removal				
Gravel Mining				
Water Export and Off-haul	AF	9400	400	-9000
Salt Export	Tons	3000	270	-2730
Net Main Basin Salt Loading (from all sources)	Tons	2200	5400	3200

This fringe basin issue is evaluated in more detail in Chapter 6 of this SMP where an approach is developed for estimating the relative percent impact from the fringe basin areas. Additional surface and groundwater monitoring is proposed in the Salt Management Monitoring Program (Chapter 6) to verify and track potential loading from future development in the fringe basins (and from recycled water irrigation throughout the valley). This information would be used to refine, as needed, Main Basin salt loading estimates and to implement additional salt management strategies to offset any such increases detected (Chapter 12).

These 2010 calculations are the basis for the projected 5,400 tons/year net salt loading used throughout this SMP to represent year 2010 steady state salt loading. Zone 7 staff used modified versions of this year 2010 "spreadsheet model" to conduct "screening level" evaluations of the impacts of implementing various salt management strategies (see Chapter 12).