California Department of Water Resources
Division of Operations and Maintenance
Water Quality Control Section

Water Quality Assessment of Floodwater Inflows in the San Luis Canal, California Aqueduct

March 1995

Pete Wilson
Governor
State of
California

Douglas P. Wheeler
Secretary for Resources
The Resources
Agency

David N. Kennedy
Director
Department of
Water Resources

Floodwater inflows from Salt Creek drain inlet on 11 January 1995.

Cover photo: Floodwater inflows from Cantua Creek drain inlet on 11 January 1995.

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Abbreviations

af	acre-feet
Ag	silver
Al	aluminum
As	arsenic
B	boron
Ba	barium
BMP	Best Management Practices
Br	bromide
Ca	calcium
$CaCO_3$	calcium carbonate
Cd	cadmium
CDWR	California Department of Water Resources
cfs	cubic feet per second
Cl	chloride
CO_3	carbonate
COV	coefficient of variation
Cr	chromium
Cu	copper
CVRWQCB	Central Valley Regional Water Quality Control Board
EC	electrical conductivity
F	fluoride
Fe	iron
Hg	mercury
I.D.	identification
K	potassium
MCL	Maximum Contaminant Level
MFL	million fibers per liter
mg/l	milligrams per liter
Mg	magnesium
Mn	manganese
mp	milepost
n	number
N	nitrogen
Na	sodium
NH_4	ammonia
NO_2	nitrite
NO_3	nitrate
NPDES	National Pollutant Discharge Elimination System
OP	Operating Procedures
P	phosphorous
Pb	lead
pH	negative log of the hydrogen ion activity
PO_4	phosphate
POC	Project Operation Control
Se	selenium
SLC	San Luis Canal
SLFD	San Luis Field Division
SO_4	sulfate
SWP	State Water Project
SWPPP	Stormwater Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
TTHMFP	total trihalomethane formation potential
USBR	United States Bureau of Reclamation
U.S.EPA	United States Environmental Protection Agency
ug/l	micrograms per liter
uS/cm	microseimens per centimeter
WDR	Waste Discharge Requirements
WQT	water quality threshold
Zn	zinc

Conversion Factors

Quantity	To Convert From Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit, Multiply Customary Unit By
Length	millimetres (mm)	inches (in)	0.03937	25.4
	centimetres (cm) for snow depth	inches (in)	0.3937	2.54
	metres (m)	feet (ft)	3.2808	0.3048
	kilometres (km)	miles (mi)	0.62139	1.6093
Area	square millimetres (mm^2)	square inches (in^2)	0.00155	645.16
	square metres (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometres (km^2)	square miles (mi^2)	0.3861	2.590
Volume	litres (L)	gallons (gal)	0.26417	3.7854
	megalitres (ML)	million gallons (10^6 gal)	0.26417	3.7854
	cubic metres (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic metres (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekametres (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic metres per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	litres per minute (L/min)	gallons per minute (gal/min)	0.26417	3.7854
	litres per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megalitres per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekametres per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lb)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb)	1.1023	0.90718
Velocity	metres per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.33456	
Specific Capacity	litres per minute per metre of drawdown	gallons per minute per foot of drawdown	0.08052	2.989
Concentration	milligrams per litre (mg/L)	parts per million (ppm)	1.0	1.0
Electrical Conductivity	microsiemens per centimetre (µS/cm)	micromhos per centimetre	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8 x °C) + 32	(°F – 32)/1.8

I. Executive Summary

Rainfall runoff from the Diablo Range occasionally is admitted into the California Aqueduct mostly through drain inlets in the San Luis Canal. Over 100 miles of the aqueduct, from Check 13 (milepost 70.89) to Check 21 (milepost 172.44), can receive this floodwater. Floodwater inflows occur during heavy rainfall and can introduce salts, metals, and organic compounds into the aqueduct. This report summarizes existing data to assess the influence of floodwater inflows on SLC water quality.

Structures that convey floodwaters into the aqueduct are called drain inlets. There are 61 drain inlets in the SLC and 74 within the jurisdiction of the San Luis Field Division. These range in size from six-inch diameter corrugated metal pipes to ten-by-six feet concrete flumes; however, the majority are 24-48 inch pipes. Floodwaters can also be pumped into the aqueduct by permanent pump emplacements and portable pumps. Where possible, detention/retention basins and ponding areas are used to reduce inflow volumes. Stop logs or control gates at drain inlets are manipulated to maximize the capacity of ponding areas and dissipate water by percolation and evaporation. Floodwaters are admitted to the SLC when the structural integrity of aqueduct levees is threatened or the capacity of bypass structures is exceeded.

Bypass structures such as overchutes and culverts convey floodwaters from the west side of the aqueduct to the east side. Bypassed water continues to flow towards the San Joaquin Valley basin trough or is ponded on easement lands. Siphons also provide flood protection by diverting aqueduct water under natural streambeds. The 21 mile stretch of aqueduct north of the SLC was designed by the State with 28 bypasses (two siphons). Conversely, the SLC was designed by the federal government with six bypasses (one siphon) at Los Banos Creek, Little Panoche Creek, Panoche Creek, Arroyo Pasajero, and two small watersheds south of O'Neill Forebay. Because of the lower bypass capacity, more floodwaters are accepted into the SLC than any other stretch of aqueduct.

Annual floodwater inflow volumes ranged from 0 to 41,938 acre-feet between 1973 to 1993. During this period, floodwater inflows occurred, on average 14 out of every 100 months. Floodwaters usually compose less than 10 percent of SLC flows. Cantua and Salt creeks are the major contributing watersheds and have accounted for 88 percent of the total inflow volume during the last seven years. Prior to 1986, Arroyo Pasajero had been the single largest contributor of floodwaters to the SLC. However, operational procedures were changed in 1986 to increase the ponding capacity in that watershed. This has substantially reduced both inflow volumes and the amount of salts and other constituents carried into the SLC from upstream watersheds.

The SLC is situated largely on alluvial deposits east of the Diablo Range. There are 24 Diablo Range watersheds or watershed groups that intersect the SLC and ten more in the stretch of aqueduct north of the SLC (34 in the San Luis Field Division). The partitioned watersheds range in size from approximately 4 to 500 square miles. Major land-use features in the watersheds include open space, crop agriculture, and rangeland. Surface water discharges or runoff from landfills, sewage treatment plants, oil production wells, and other industrial facilities are prohibited or strictly regulated by the regional water quality control board. Although nonnatural land uses may have some effect, the natural soil geology is a predominant factor affecting floodwater quality.

The water quality of floodwaters is strongly influenced by ancient marine sediments that dominate the surface geology of SLC watersheds. Salts and other elements such as selenium are leached from the deposits and transported downstream within rainfall runoff. Saline springs in a minority of the watersheds also augment floodwater salinity.

The water quality of floodwater inflows was evaluated using data from 1986 through 1993. Data from individual drain inlets were combined and averaged by watershed to reflect runoff waters similar in their geochemical make-up. Averages were compared to water quality thresholds which include Article 19 objectives and Maximum Contaminant Levels to determine relative levels. Parameters that exceeded WQTs in the major contributing watersheds were most likely to affect SLC water quality but do not imply impacts. The major findings were:

1. Total dissolved solids, hardness, sulfate, and boron detected in floodwater inflows were above WQTs in a majority of the sampled watersheds. The salts are leaching from naturally occurring marine deposits in the Diablo Range. All were above WQTs in the major contributing watersheds.
2. Minor elements were not universally elevated in floodwater inflows; however, aluminum, iron, manganese, and selenium exceeded the respective WQTs on a few occasions. None of the exceedences occurred in the major contributing watersheds.
3. Nutrients were not universally elevated in floodwater inflows, however, nitrate exceeded the WQT in two watersheds. None of the exceedences occurred in the major contributing watersheds.
4. Total organic carbon and total suspended solids were elevated in floodwater inflows.
5. Herbicides and pesticides were detected in about half of the floodwater samples analyzed. More than half of the detections were from the major contributing watersheds.
6. Salt and Cantua creeks are sources of asbestos to the aqueduct, although complete assessment was hindered by high detection limits caused by elevated turbidity levels.

SLC water quality was assessed using monthly grab sample data from Checks 13 and 21. Check 13 represents the upstream station unaffected by SLC floodwaters and Check 21 is downstream all SLC drain inlets. Upstream/downstream comparisons were performed for parameters that were elevated in floodwaters from the major contributing watersheds (Salt and Cantua creeks) and included TDS, hardness, sulfate, and boron. Data from the rainy season months (November through April) of 1980, 1983, and 1986 were assessed. For asbestos, upstream/downstream comparisons were performed for the rainy season months of 1992 and 1993. Pesticides and TSS were also assessed. The major findings were:

1. TDS, hardness, sulfate, and boron concentrations increased between Checks 13 and 21 for several rainy season months during 1980 and 1983 but not 1986. With the exception of boron, the Article 19 objectives for these parameters were periodically exceeded at Check 21 during 1980 and 1983.
2. Floodwater inflows, at times, contributed a considerable amount of TSS to the aqueduct.
3. Floodwater inflows rarely influenced pesticide levels in the SLC.
4. Although asbestos was rarely detected in the SLC, assessment of the effects of floodwater inflows was limited by high detection limits caused by elevated turbidity levels.

Conclusions

Floodwater inflows have caused local, temporary, increases of some water quality constituents in the aqueduct during periods when rainfall has been unusally heavy. During the 1980 and 1983 rainy seasons, concentrations of TDS, sulfate, hardness, and boron increased in the SLC between Checks 13 and 21 during a few months when floodwater inflows were high. An increase in salts was not observed during the 1986 rainy season. Operational modifications at Arroyo Pasajero in 1986 have reduced overall floodwater inflows and will result in smaller salt increases for future rainy seasons similar to 1980 and 1983.

Metals, nutrients, and organic chemicals were not universally elevated in floodwater inflows. Iron, aluminum, selenium, magnesium, total organic carbon, and nitrate were detected at high levels from a few of the smaller watersheds but did not influence aqueduct water quality. Floodwater inflows are highly turbid and contribute somewhat to aqueduct sediment loads.

Recommendations

The following monitoring strategies are recommended to fill information gaps with emphasis on collecting data from specific watersheds and water quality constituents of concern.

1. Drain inlets from the major contributing watersheds (Salt, Cantua, and, possibly, Little Panoche creeks) should remain the primary cyclic monitoring locations.
2. Analyze minerals in floodwater inflows from watersheds with no existing data.
3. Analyze selenium in floodwater inflows from the Monocline Ridge area.
4. Analyze minerals in ground water from sump pumps.
5. Inspect the Kettleman Hills Group watershed to determine if there are any unusual pollutant sources.
6. Analyze settleable solids in floodwater inflows from the major contributing watersheds.
7. Include TSS and TOC analyses in routine grab sampling at Checks 13 and 21 during the months of January, February, and March.

II. Introduction

The joint-use stretch of California Aqueduct, or San Luis Canal, extends over 100 miles from Check 13 to Check 21. It was designed and built by the U.S. Bureau of Reclamation to distribute water to both agricultural and municipal users. It was also built with drain inlet structures to admit floodwaters generated west of the SLC. Rainfall runoff from the Diablo Range flows across alluvial deposits and is admitted to the SLC when the capacity of ponding areas or bypass structures is exceeded. Floodwater inflows contain elevated salts and other compounds that have been leached or flushed from the watershed. Potential impacts to the State Water Project include increased dredging of sediments, increased corrosion potential from salts, increased water treatment costs from elevated suspended solids, as well as taste and odor problems from salts and nutrients.

Past assessments by the Department concluded that floodwater inflows would likely affect SLC water quality but were limited by a small database (CDWR 1962; Dettloff 1964). Water quality monitoring conducted prior to SLC construction detected total dissolved solids above 700 ppm in foothill streams of the Diablo Range. Boron concentrations were also found to be "excessive". When taken into the SLC, floodwaters were estimated to increase aqueduct TDS by 47 and 315 mg/l for a 2- and 25-year flood event, respectively. The increases were predicted to exceed the numerical objective and adversely affect the quality of Project water. In 1978, a Department report concluded that a thorough investigation of SLC floodwater inflows was needed (Gage 1978). More recently, a sanitary survey conducted for the Department recommended a review (and alteration if necessary) of existing monitoring strategies to improve the Department's ability to assess aqueduct impacts from periodic floodwater surges (Brown and Caldwell 1990).

A comprehensive analysis of floodwater inflows and their influence on SLC water quality was performed in this report. Individual study objectives were:

1. Compile and interpret recent floodwater quality data (1986–93).
2. Investigate current watershed features and their influence on water quality.
3. Assess changes in SLC water quality from past floodwater inflows.
4. Compare the relative contribution of salts and other important constituents from floodwater inflows.
5. Identify any information gaps and propose monitoring strategies to fill them.

III. Study Area Description

The study area scope encompasses a stretch of California Aqueduct within the San Luis Field Division. This includes the SLC and a reach of aqueduct north of the SLC from milepost 45.97 to milepost 66.85 (Check 12). Both were included in this study to compare state- and federally-designed floodwater features and to utilize all water quality data. This report focuses primarily on drain inlets in the SLC since most floodwaters admitted to the California Aqueduct occur there. In this chapter, watershed features that could affect floodwater quality were identified. A description of the SLC and it's floodwater structures follows.

Watershed Description

Most floodwater inflows to the SLC originate as watershed runoff from the eastern slope of the Diablo Range, part of the southern Coastal Range. The Diablo Range extends from San Francisco Bay to Polomo Creek south of Kettleman City (Davis 1961). The topography of this land varies from mildly sloped foothills, such as Panoche and Ciervo Hills, to rugged and steeply sloped mountains making up the headwaters (Bull 1964).

The SLC is situated on alluvial deposits east of the Diablo Range. Thirty-four watersheds or watershed groups intersect the California Aqueduct in the San Luis Field Division, 24 of which are west of the SLC (Table 1 and Figure 1). Watershed groups encompass smaller watersheds with flows that do not maintain their distinction at the aqueduct. The partitioned watersheds range in size from approximately 4 to 500 square miles.

Lands draining to the SLC have been artificially altered to a certain extent. Major land-use features include open space, rangelands, and agriculture; however, urban areas, landfills, oil production wells, and other facilities also exist to a small extent west of the SLC. Regardless of these land-use features, the natural geology of the Diablo Range is a predominant factor influencing floodwater quality.

Natural Features

The geochemistry of floodwaters west of the SLC is strongly controlled by soil characteristics within the individual watersheds (Davis 1961). Ancient ocean deposits, such as marine sandstones, dominate the Diablo Range and are up to 1,000 feet thick in some places (Davis et al. 1959). These deposits contain concentrated salts such as sulfate, chloride, and magnesium which are easily dissolved in water. Sulfate originates from both marine sediments and continental deposits prevalent throughout the Diablo range. High chloride concentrations in Salt Creek (Merced County) and Little Panoche Creek result from contact with the Panoche Formation. Selenium is concentrated within the marine sedimentary deposits defined as the Moreno and Kreyenhagen formations (Tidball et al. 1986). These formations are intermixed with others of low selenium content in most of the Diablo Range watersheds but dominate the Monocline Ridge surface geology (Gillium et al. 1989). Serpentine exposures produce magnesium bicarbonate waters that are unique to certain streams such as San Carlos Creek (in the Panoche Creek watershed), Cantua Creek, and White Creek (in the Arroyo Pasajero watershed).

Table 1. Watersheds Draining West of the California Aqueduct in the Study Area.

Watershed [1]				
I.D. # [2]	Milepost Range	Name	Square Miles [3]	Major Drainages and Their Tributaries
1	45.97 – 47.10	Crow Creek	28	Crow Creek
2	47.10 – 50.63	Crow Creek Hills Group	4	
3	50.63 – 52.03	Oristimba Creek	140	Oristimba Creek (siphon): Oso Creek
4	52.03 – 56.20	Bennett Valley Group	34	Bennett Valley Creek
5	56.20 – 57.67	Garzas Creek	57	Garzas Creek (siphon): Whitney Canyon
6	57.67 – 61.73	Mustang Creek	8	Mustang Creek
7	61.73 – 65.00	Quinto Creek	32	Quinto Creek
8	65.00 – 66.10	Romero Creek	24	Romero Creek
9	66.10 – 66.85	O'Neill Forebay drng, N.		
10	66.85 – 70.60	O'Neill Forebay		San Luis Reservoir. Delta–Mendota Canal
San Luis Canal				
11	70.60 – 74.10	O'Neill Forebay drng, S.		
12	74.10 – 74.80	Billie Wright drainage	25	Billie Wright Creek
13	74.80 – 78.36	Volta Group		
14	78.36 – 79.50	Los Banos Creek	157	Los Banos Creek: Los Banos Reservoir: N. & S. Forks Los Banos Creek, Wildcat Creek
15	79.50 – 82.00	Salt Creek Group (Merced Co.)	22	Salt Creek
16	82.00 – 84.40	Ortigalita Creek Group	57	Ortigalita Creek: Piedra Azul Creek
17	84.40 – 87.78	Dos Amigos	14	
18	87.78 – 89.55	Laguna Seca Creek	11	
19	89.55 – 93.70	Etoheverry Group	7	Laguna Seca Creek
20	93.70 – 95.40	Wildcat Canyon	20	Wildcat Canyon
21	95.40 – 96.78	Little Panoche Creek	101	Little Panoche Creek: Little Panoche Reservoir: Vasquez Creek, Mercey Creek, Mine Creek
22	96.78 – 108.50	Panoche Hills Group	75	Capita Canyon. Moreno Gulch
23	108.50 – 110.85	Panoche Creek	302	Panoche Creek (siphon): Las Aquilas Creek, Bitterwater Canyon, Clough Canyon
24	110.85 – 113.82	Tumey Hills Group	29	Tumey Gulch
25	113.82 – 119.50	Monocline Ridge Group	50	
26	119.50 – 127.90	Arroyo Ciervo Group	8	Arroyo Ciervo
27	127.90 – 131.55	Arroyo Hondo Croup	26	Arroyo Hondo
28	131.55 – 134.88	Cantua Creek Group	48	Cantua Creek: Arroyo Leona
29	134.88 – 138.24	Salt Creek Group (Fresno Co.)	25	Salt Creek: Martinez Creek
30	138.24 – 141.90	Jordan Group	11	Domengine Creek
31	141.90 – 144.70	Ford Group	20	
32	144.70 – 154.11	Skunk Hollow	12	
33	154.11 – 163.95	Arroyo Pasajero	500	Arroyo Pasajero: *Los Gatos Creek*: Bear Canyon, White Creek, Mud Run, Nuez Canyon, Salt Canyon, Warthen Creek, Jacolitos Creek. *Zapato Chino Creek:* Cedar Canyon, Garcia Canyon, Canoas Creek
34	163.95 – 172.44	Kettleman Hills Group		Arroyo Largo: Arroyo Torcido

[1] *Refer to Figure 1 for areal location.*
[2] *I.D. # = Identification number assigned to the watershed.*
[3] *The square miles for Billie Wright Creek are the combined areas from the O'Neill Forebay drainage (South), Billie Wright drainage, and the Volta Group.*

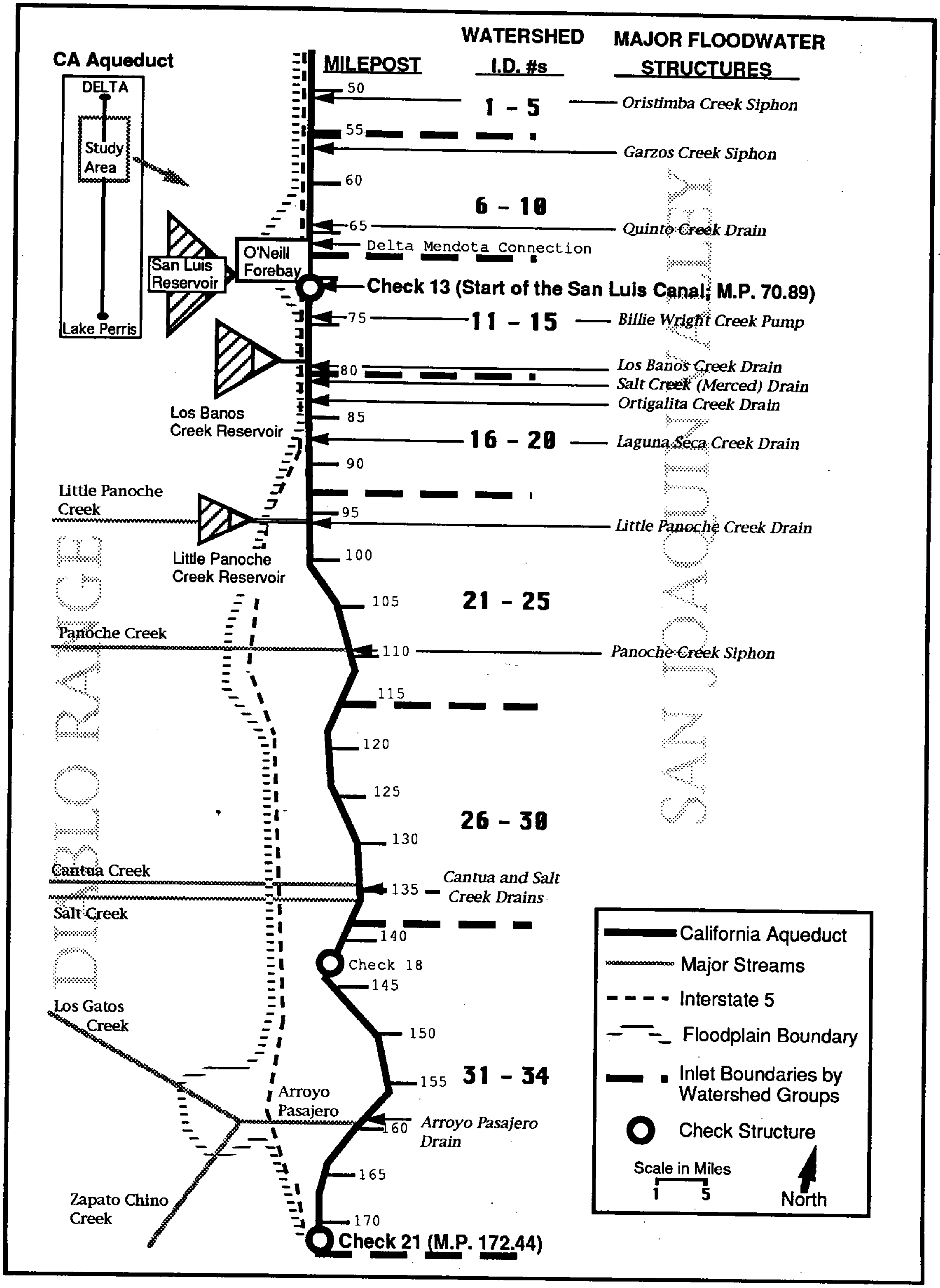

Figure 1. General Schematic of the California Aqueduct in the San Luis Field Division.

Asbestos also originates from naturally occurring minerals of the serpentine group (e.g., chrysotile; Mottana et al. 1978). The New Idria serpentinite body covers 48 square miles along the central part of the Diablo Range in western Fresno County and eastern San Benito County (Faria, pers. comm.). Watersheds with serpentine soils include Cantua Creek and Los Gatos Creek (a tributary of Arroyo Pasajero watershed). Serpentine (or similar ultramafic intrusives) compose, respectively, 13 and 6 percent of the watershed surface area of these creeks (Davis 1961). Waterborne asbestos originates from the erosion of natural soils and inactive chromite, mercury, and asbestos mine sites (Faria, pers. comm.).

Two types of streams drain the Diablo Range: 1) ephemeral streams in inter-fan areas and 2) the larger intermittent streams that create major alluvial fans (Bull 1964). Intermittent streams such as Panoche, Cantua, and Los Gatos creeks receive ground water flow along their entire length for a few weeks after most rainy seasons. Ephemeral streams drain the smaller gullies and usually flow only as a result of high precipitation.

Water from highly saline springs can augment stream flow. Some of the springs emanating from the Diablo Range are thought to originate as ancient seawater (connate water) trapped within the sedimentary deposits (Davis 1961). Connate water is characterized as dilute sea water (very saline). Springs of this nature are known or suspected within the watersheds of both Salt creeks (Fresno and Merced counties), Panoche Creek, Billie Wright Creek, Little Panoche Creek, Arroyo Ciervo, Etoheverry, and possibly others.

Water from the Diablo Range traverses alluvial deposits that are between the foothill base and the SLC. This distance ranges up to about 20 miles but is more commonly between 5 and 10 miles (Figure 1). Alluvial fans are composed of erosional deposits carried down from the eastern slope of the Diablo Range during high flow periods (Bull 1964).

An alluvial fan generally has three segments: the fanhead (where the creek meets the fan), midfan, and distal fan (Bull 1964). The SLC sits largely on the fanhead and mid-fan segments of Diablo Range alluvial deposits. Deposits near the fanhead are 80–100 percent sand and gravel (Laudon and Belitz 1989). Midfan deposits range from coarse material found in stream channels to finer grained sediments in-between stream beds.

Beneath the alluvium is an extensive lacustrine deposit of low permeability called the Corcoran Clay Member of the Tulare Formation (Johnson et al. 1968). This formation is responsible for perched ground water in the semiconfined zone (Belitz and Heimes 1989). The depth of alluvium to the clay barrier in general declines with distance from the Diablo Range. For those sections of the SLC on on the flood plain, the depth of alluvium varies between 100 to 800 feet (Miller et al. 1971 in Belitz and Heimes 1989). However, portions of the aqueduct extend off the valley floor and into the foothill zone where near-surface ground water can be present.

Depositional material between the major alluvial fans (interfan areas) are different in composition than water-laid alluvium (Bull 1964). Interfan areas below the Diablo Range are made up of mudflow from ephemeral streams. Mudflows are the result of slumping and mass wasting of streambanks during heavy rainfall. Because the smaller watersheds do not generate large stream flows, the eroded earth material is not extensively distributed. Mudflows associated with ephemeral streams are poorly sorted and coalesce with the larger alluvial fans but do not extend very far into the valley floor. Mudflows usually have a higher mineral content available for dissolution largely because the leaching process has been limited (Swain, pers. comm.).

The Diablo Range is the largest source of selenium in the San Joaquin Valley (Tidball et al. 1986). Selenium is elevated in alluvium between San Luis Reservoir and Cantua Creek but is highly concentrated in the mudflow zone at the base of Monocline Ridge. The high selenium levels detected there can be explained, in part, by the surface geology of Monocline Ridge and to a lesser extent by the small runoff volumes which restrict off-site transport (Presser et al. 1990). Alluvium from other watersheds contain a diverse mixture of sediment types (with varying selenium levels) that tend to dilute downstream selenium levels.

The distribution of other elements associated with Diablo Range alluvium is not as well studied as selenium. Soil salinities are generally greatest at the distal end of fans and lowest at the fanheads (Presser, et al., 1990). Calcium with minor amounts of sulfur and carbon (probably as the anions sulfate and carbonate) are coprevalent in alluvium at the western edge of the valley downstream from Monocline Ridge (Tidball, et al., 1986).

Agriculture

Livestock rangeland grazing exists west of the SLC where numerous wildlife species also inhabit the area. Animal excrement is a potential source of salts, nutrients, enteric bacteria and viruses, and parasites. In addition to the water quality problems from animal excrement, rangeland grazing can exacerbate watershed erosion and increase runoff turbidity.

In July, 1991, the State Water Resources Control Board and the U.S. Natural Resources Conservation Service (formerly Soil Conservation Service) formally agreed on a set of goals designed to reduce human-induced erosion (Appendix K). These goals include developing statewide policy on erosion control, creating county erosion control committees to solicit local input and encourage voluntary implementation, establishing educational programs, and refining Best Management Practices through demonstration projects .

Two major livestock facilities also exist west of the SLC. Harris Ranch feedlot and Cal-Star Dairy are in the Jorden Group and Wildcat Canyon (and possibly Etoheverry Group) watersheds, respectively. Site runoff from these facilities can contain high levels of salts and nitrogen products such as ammonia, urea, and nitrate. However, runoff from these facilities is retained as defined in state agreements or enforcement regulations.

Livestock facilities west of the SLC implement BMPs with guidance and general oversight from the Central Valley Regional Water Quality Control Board (Appendix L). Those facilities that impact water quality as a result of their operations may be subject to enforcement measures or permit under the National Pollutant Discharge Elimination System. BMP practices developed by the SWRCB include retaining water from manure storage areas, providing overflow protection at confinement facilities, and applying washwater and surface drainage to crop lands (Appendix L). The Department also has a specific agreement with Harris Ranch to retain site runoff (Appendix M).

Approximately 20 to 30 percent of the watershed area west of the SLC is dedicated irrigable lands (portions of Westlands, Pleasant Valley, and San Luis water district lands). Irrigable lands include those that could be farmed but may be fallow due to factors such as water availability. For instance, the amount of fallowed lands in Westlands Water District averages around 7 percent during normal water years and increases when water availability decreases (Stynard, pers. comm.).

Rainfall runoff from plant agriculture (orchards and row crops) can contain fertilizers and pesticides. Factors affecting the concentration of agricultural chemicals in floodwaters include application rate and time, rainfall characteristics, first flush effects, and degradation rate.

The SWRCB and the Department of Pesticide Regulation have formalized a coordinated program to identify pesticides determined to be particularly toxic or problematic. Data submitted in the registration process is scrutinized by these agencies to identify pesticides of concern (Appendix N). Regulations regarding use, application procedures, and management practices are modified when existing ones would not adequately protect surface waters. Further, if agricultural drainage negatively impacts a receiving water, the discharger will be subject to discharge prohibitions or regulation by permit. Information regarding these regulations will be disseminated and dischargers will be advised to voluntarily implement management practices that result in full compliance.

Urbanized Areas

The incorporated cities of Huron and Coalinga in the Arroyo Pasajero watershed compose less than 0.5 percent of the total watershed area west of the SLC. The most common pollutants in urban runoff include oil and grease, lead, copper, zinc, and cadmium. Like most small cities, urban runoff is discharged untreated. However, urban runoff would be highly diluted by natural runoff due to the relatively small amount of urbanized land west of the SLC.

Industrial and Domestic Facilities

Treated domestic sewage generated west of the SLC is regulated by the CVRWQCB. Sewage from the cities of Coalinga and Huron must be percolated in ponding areas or applied to crop and pasture lands. The cities are prohibited from discharging to surface waterways by Waste Discharge Requirements (Ramirez, pers. comm.; Granger, pers. comm.). Domestic sewage in unincorporated areas is treated by septic/leach-line systems.

Oil production wells are in watersheds from Arroyo Pasajero south. Briny ground water is brought to the surface as a byproduct of oil extraction. This wastewater is either reinjected into saline aquifers or dissipated by evaporation/percolation basins (Gray, pers. comm.). Oil production facilities are restricted from discharging to surface waters based on an agreement between the state Department of Fish and Game, the CVRWQCB, and the state Division of Oil and Gas (Appendix P; Yee, pers. comm.).

Class I through Class III landfills exist in several watersheds including Arroyo Pasajero, Kettleman Hills, and Billie Wright Creek (water from this creek is not allowed into the aqueduct). Class I and II landfills (hazardous and designated, respectively) are regulated by permit and are required to develop a Storm Water Pollution Prevention Plan which may include the retention of site runoff from a 100-year storm, site specific water quality conditions, and sediment catch basins.

Runoff from certain industrial facilities is regulated by the CVRWQCB with a statewide general NPDES permit (Appendix O). The permit requires development of a SWPPP as a requisite for continued operation. SWPPP conditions may include sediment traps, site specific water quality limits, storing chemical materials in controlled areas, employing clean "housekeeping" practices, and water quality sampling.

Inactive Mines

Inactive mine drainage can be a source of heavy metals in floodwater inflows. Monitoring data from two large inactive mines in the Diablo Range (New Idria and Mt. Diablo) indicate that mercury mines are a concentrated source of aluminum, iron, copper, zinc, mercury, and cadmium. Inactive mines west of the SLC can be found from Panoche Creek south (based on United States Geological Survey map symbols). Miners were largely after mercury concentrated in cinnabar deposits. Mine drainage is generated when geological formations are exposed to the air. Metals are solubilized and transported downstream in runoff water. One large inactive mine (New Idria) exits in the Panoche Creek watershed but is not a threat due to a siphon emplacement on the aqueduct. Not much is known about other smaller mercury and hard rock mines in the Diablo Range.

Because of the aridity of eastern slopes in the Diablo Range, perennial mine drainage would not be common regardless of mine size. However, abandoned waste rock piles (tailings and gange material) exist at all mine sites and are a source of pollutants. Rainfall facilitates the release of rock-bound metals by oxidation and transports them off-site through erosion. Under certain circumstances, the CVRWQCB will support action to remediate inactive mines that impact receiving waters using governmental or other funding sources (Appendix Q).

Inactive mines can also contribute to asbestos in floodwater inflows. Inactive asbestos mines exist in the Cantua Creek watershed and in the Arroyo Pasajero watershed on White and Pine creeks, tributaries of Los Gatos Creek (CDWR 1990; Faria, pers. comm.). Asbestos is flushed from mine site waste rock piles within rainfall runoff. During past significant storms, White Creek has flowed milky white with asbestos and left a white coating on stream banks (CDWR 1990). Two abandoned asbestos mines in the Los Gatos Creek watershed (Atlas and John-Mansville Coalinga) are on the U.S.EPA's Superfund list for asbestos and are presently undergoing remediation (U.S.EPA 1994b).

Climate

The San Joaquin Valley has a semi-arid climate. Precipitation amounts in the study area generally decrease with declining elevation and southerly latitude (Davis, 1961). Near the southern end of the valley at Buttonwillow, for instance, the annual rainfall total averages around 5 inches whereas at Tracy, to the north, the rainfall total is around 9.5 inches. Higher elevation stations can average almost 20 inches of precipitation a year. The annual rainfall near the town of Panoche averaged around 10.8 inches from 1973 to 1993. Panoche is approximately midway along the SLC and is also the approximate mid-elevation (1,200-1,300 feet MSL) for much of the Diablo Range.

Many factors make the relationship between rainfall and floodwater inflows highly unpredictable. These include the amount of impervious surface, soil permeability, soil porosity, time since incipient rainfall, and the individual characteristics of a rainfall event such as duration, intensity, geographical variance, etc.

Joint-Use Facilities

The SLC is a section of California Aqueduct used jointly by the SWP and the federal Central Valley Project. It extends over 100 miles from Check 13 (milepost 70.89) to Check 21 (milepost 172.44; Figure 1). Other joint-use structures include the San Luis Reservoir and O'Neill Forebay. These two facilities are used to store and release water to meet variable demands throughout the year. Flood control reservoirs were built on Little Panoche and Los Banos creeks to capture rainfall runoff from those watersheds. The joint-use facilities were designed and constructed by the USBR in cooperation with, and consultation by, the State (CDWR 1974, Vol I). The State contributed 55 percent of the total construction costs and has sole responsibility for it's operation, maintenance, and replacement under the same cost sharing arrangement.

Floodwater Structures

Major floodwater structures include drain inlets and bypasses. A brief description of these and other floodwater structures is given below. Detailed physical characteristics are in Table A-1 of Appendix A.

Drain Inlets

Structures that convey floodwaters into the aqueduct are called drain inlets. There are 60 drain inlets in the SLC and 73 within the study area (Table 2). They range in size from six-inch diameter corrugated metal pipes to ten-by-six feet concrete flumes; however, the majority are 24-48 inch pipes (Table A-1). Almost all drain inlets are situated on the right bank (west side) of the aqueduct. Smaller pipes draining adjacent service roads (called toe drains) were not included in this estimate. According to Brown and Caldwell (1990) there are 227 toe drains in the SLC.

Permanent and Portable Pumps

Floodwaters can also be pumped into the aqueduct by permanent pump emplacements and portable pumps. Most permanent floodwater pumps are on the SLC between milepost 70.60 and 74.80 (Table 2). Pump pads are used in conjunction with portable pumps and are on the SLC between Little Panoche Creek and Arroyo Pasajero, where ponding against the levee is common. With the exception of Salt and Cantua creeks, the aqueduct in this stretch is not equipped with either fixed inlets or bypasses. Floodwaters can also be pumped into the aqueduct at just about any location on the levee using portable pumps.

Sump pumps on the SLC pump ground water into the aqueduct to protect the cement liner from rupturing due to hydrostatic pressure (CDWR 1974). Sump pumps are on the SLC between mileposts 74.80 and 78.36, although, there are many more north of O'Neill Forebay (Table 2).

Table 2. Floodwater Structures on the California Aqueduct in the Study Area.[1]

Watershed			Drain Inlets			Bypasses		Pumps[5]		
I.D. #[2]	Milepost Range	Name	No.[3]	Opening Size (sq-ft)	% of Total[5]	No.[3]	Size (sq-ft)	Sump	Pad	Perm.
1	45.97 – 47.10	Crow Creek	0	0	0.0	1	402	0	0	0
2	47.10 – 50.63	Crow Creek Hills Group	1	7	0.7	5	62	3	0	0
3	50.63 – 52.03	Oristimba Creek	1	3	1.0	1	siphon	2	0	0
4	52.03 – 56.20	Bennett Valley Group	6	33	1.0	5	110	11	0	0
5	56.20 – 57.67	Garzas Creek	0	0	4.0	1	siphon	2	0	0
6	57.67 – 61.73	Mustang Creek	3	24	7.0	6	129	4	0	0
7	61.73 – 65.00	Quinto Creek	0	0	7.0	6	382	7	0	0
8	65.00 – 66.10	Romero Creek	1	2	7.0	2	198	3	0	0
9	66.10 – 66.85	O'Neill Forebay drng, N.	1	1	7.0	1	7	3	0	0
10	66.85 – 70.60	O'Neill Forebay			7.0			0	0	0
		Subtotal	**13**	**70**		**28**		**35**	**0**	**0**
San Luis Canal										
11	70.60 – 74.10	O'Neill Forebay drng, S.	6	32	10.0	1	30	0	0	4
12	74.10 – 74.80	Billie Wright drainage	0	0	10.0	1	30	0	0	1
13	74.80 – 78.36	Volta Group	8	57	16.0	0	0	8	0	0
14	78.36 – 79.50	Los Banos Creek	0	0	16.0	1	180	0	0	0
15	79.50 – 82.00	Salt Creek Group (Merced Co.)	4	68	23.0	0	0	0	0	0
16	82.00 – 84.40	Ortigalita Creek Group	4	67	29.0	0	0	0	0	0
17	84.40 – 87.78	Dos Amigos	6	64	35.0	0	0	0	0	1
18	87.78 – 89.55	Laguna Seca Creek	3	94	45.0	0	0	0	0	0
19	89.55 – 93.70	Etoheverry Group	3	92	54.0	0	0	0	0	0
20	93.70 – 95.40	Wildcat Canyon	0	0	54.0	0	0	0	0	0
21	95.40 – 96.78	Little Panoche Creek	2	140	68.0	1	90	0	0	0
22	96.78 – 108.50	Panoche Hills Group	2	13	69.0	0	0	0	2	0
23	108.50 – 110.85	Panoche Creek	0	0	69.0	1	siphon	0	0	0
24	110.85 – 113.82	Tumey Hills Group	0	0	69.0	0	0	0	2	0
25	113.82 – 119.50	Monocline Ridge Group	0	0	69.0	0	0	0	4	0
26	119.50 – 127.90	Arroyo Ciervo Group	0	0	69.0	0	0	0	9	0
27	127.90 – 131.55	Arroyo Hondo Group	0	0	69.0	0	0	0	2	0
29	131.55 – 134.88	Cantua Creek Group	3	162	85.0	0	0	0	0	0
29	134.88 – 138.24	Salt Creek Group (Fresno Co.)	3	23	87.0	0	0	0	1	0
30	138.24 – 141.90	Jordan Group	0	0	87.0	0	0	0	3	0
31	141.90 – 144.70	Ford Group	0	0	87.0	0	0	0	3	0
32	144.70 – 154.11	Skunk Hollow	0	0	87.0	0	0	0	4	0
33	154.11 – 163.95	Arroyo Pasajero	4	80	95.0	1	60	0	3	0
34	163.95 – 172.44	Kettleman Hills Group	12	49	100.0	0	0	0	1	0
		Subtotal (San Luis Canal)	**60**	**941**		**6**		**8**	**34**	**6**
		Grand Total	**73**	**1011**		**34**		**43**	**34**	**6**

[1] Adapted from SLFD Water Operations Manual OP-35OR, June 1989. See also Table A-1 for detailed characteristics of individual structures.
[2] Refer to Figure 1 for areal location.
[3] Number of drain inlets or bypasses within each milepost range.
[4] Cumulative percent-of-total of the drain inlet opening size.
[5] Sump pumps, pump pads, and permanent pumps.

Bypasses (Culverts, Overchutes, and Siphons)

Bypass structures such as overchutes and culverts convey floodwaters from the west side of the aqueduct to the east side. There are 34 bypasses in the study area, six of which are on the SLC (Table 2). Floodwaters are conveyed over the aqueduct in overchutes or under the aqueduct through evacuation culverts. Bypassed floodwaters continue to flow east or are ponded at designated sites. Evacuation culverts and overchutes are similar in size and design to drain inlets (see Table A–1). Siphons also provide floodwater protection by diverting aqueduct water under natural stream channels. Siphons are installed below major watersheds where runoff volumes are substantial. One of three siphons in the study area is on the SLC at Panoche Creek.

Bypass/Drain Inlet Design Capacity Ratios

The bypass/drain inlet design capacity ratio (or bypass capacity) was calculated as the square area of all bypass openings divided by the square area of all drain inlet openings. Ratios were compared between the federally–designed SLC and the State–designed stretch of aqueduct north of the SLC.

The bypass capacity of the aqueduct is more than 45 times greater than that of the SLC. The ratio is approximately 0.4 for the SLC and over 18 for the State aqueduct. The difference in ratios is actually larger if portable and permanent pumps in the SLC were included.

Ponding Areas

Ponding areas exist in most of the larger watersheds. In many instances, ponding areas are simply Department easement lands extending up to several hundred feet from the aqueduct levee. Stop logs or control gates at drain inlets are manipulated to maximize the capacity of ponding areas and dissipate water by percolation and evaporation. Ponding areas also serve to settle out particulate matter. Major ponding areas are listed in Table A–2. Detention/retention reservoirs were built on Los Banos and Little Panoche creeks to intercept runoff from those watersheds (CDWR 1974, Vol III).

Alluvium deposits can substantially reduce the holding capacity of ponding areas. For instance, the total ponding capacity of Arroyo Pasajero was reduced from approximately 16,500 acre–feet in 1969 (CDWR 1984) to 4,373 af presently on Department easement lands (CDWR 1993). Approximately 2 million cubic yards of alluvium were deposited there during 1983 alone (Anderson, pers. comm.).

Project Instructions and Orders for Operating Floodwater Structures

Operational procedures for floodwater structures are periodically amended to provide the greatest possible protection from floodwater impacts. Project Operations and Maintenance Instruction No. OP–13 (last amended 6/9/93) applies to inputs along the entire California Aqueduct. Standing Order No. SLFD–OP–93–8D (last amended 11/24/93) applies specifically to flood control operations at Arroyo Pasajero. Standing Order No. SLFD–OP–91–20E applies to Little Panoche Creek structures. These and other related procedures are summarized below and presented in full in Appendices E through J.

Project Operations and Maintenance Instruction No. OP–13: Outlined responsibilities address the acceptance, monitoring, and disposal of floodwaters intersecting the California Aqueduct. Specifically, the following actions are to be implemented by the appropriate personnel:

A) *Prevent or minimize inflow of floodwater into the aqueduct.* Every reasonable effort will be made to minimize the inflow of floodwater to the aqueduct. Actions relate primarily to maximizing the capacities of ponding areas and bypasses. Where possible, floodwater will be routed past the aqueduct through overchutes or evacuation culverts. Where feasible, inlet gates, stop logs, and other control measures will be used to pond floodwaters and dissipate them through evaporation and percolation. Floodwater will only be accepted into the aqueduct when rising water levels threaten the integrity of the aqueduct. Other than floodwater, no unscheduled water (for which there has not been prior agreement or contract with the Department) will be admitted to the aqueduct.

B) *Coordinate aqueduct operation during periods when flood drainage inlet gates are open.* Field divisions are responsible for measuring inflows, informing the Project Operation Control office of inflows before and during the inflow period, monitoring the quality of floodwater inflows, and applying all appropriate operating instructions. The POC is responsible for action taken when water is accepted into the aqueduct. Project Operation Control actions include revising pump schedules and gate settings and notifying the appropriate field division of the changes made.

C) *Monitor water quality of floodwater to the California Aqueduct and SLC.* When floodwater inflows to the aqueduct occur, field division staff will collect water samples. Gravity flow drains and permanent pump sites will be sampled when feasible. Flow measurements will be obtained from pump run-time, visual estimates, and stage-discharge curves where available. At portable pump sites, water samples will be collected from the ponded water prior to pumping. Additional monitoring will be conducted in the aqueduct at any bridge or check station immediately downstream from major drain inlets.

D) *Coordinate disposal of floodwater taken into the aqueduct.* The intent of this procedure is to confine sediment (discharged from drain inlets) in the aqueduct to as small an area as possible. This will be accomplished by reducing flow rates and disposing of floodwater taken into the aqueduct. To decrease aqueduct flow, Dos Amigos Pumping Plant will reduce pumping to meet San Joaquin Valley demands only. Disposal of floodwaters already admitted to the aqueduct will be accomplished by first using the water for Project deliveries and using available storage space in the aqueduct. Secondly, floodwater in the aqueduct would be used to fill southern California reservoirs. And last, excess floodwater will be released through the Kern River Intertie and other wasteways or canal drains. The use of these methods and the order in which they are implemented shall be coordinated between the POC and the responding field division.

Standing Order No. SLFD-OP-8D: This order outlines interim procedures for operating the Arroyo Pasajero flood control facilities. It mandates that ponding areas and the evacuation culvert be utilized first before water is admitted to the aqueduct. By using Department easement and non-easement ponding areas, the combined retention volume is adequate for a 100-year storm event. The order was enacted to minimize inflows of asbestos-laden sediments. General control procedures are to be implemented in the order given below:

A) *Water ponding at existing retention basin.* The existing retention basin between the training dike (Dorris Avenue) and Gale Avenue shall be used to store the initial inputs.

B) *Water ponding at proposed retention basin expansion.* If ponded water rises above elevation 328.0 at Gale Avenue, it shall be allowed to flow south into the proposed basin expansion between Gale Avenue and Avenal Cutoff Road.

C) *Divert floodwater under the aqueduct to the east with evacuation culvert.* If ponded water is predicted to rise above elevation 328.0 at Gale Avenue after the basin to the south is filled, the gates to the evacuation culvert shall be opened to pass water under the aqueduct to the east.

D) *Allow water into the aqueduct through Gale Avenue drain inlets.* If the floodwater level is predicted to exceed elevation 328.0, after the evacuation culvert gates are open, the inlet structure shall be opened and floodwater released into the aqueduct.

Standing Order No. SLFD-OP-91-20E: This order dictates the operational procedures for Little Panoche Creek floodwater structures. Stoplogs in front of both the culvert and drain inlet will be manipulated to limit the inflow of sediment to the aqueduct. One stoplog will be placed in front of the culvert and four in front of the drain inlet. Initial floodwater flows to the ponding area will be allowed to flow through the culvert. When a sufficient amount of sediment has settled out, one stoplog will be removed from the drain inlet. If creek flow exceeds the capacity of the drain inlet, stoplogs will be removed from the culvert and the entities on the notification list will be apprised of the release.

Los Banos and Little Panoche Creek Dam Outlet Releases: At the Los Banos Creek Retention Dam, 14,000 af of space will be maintained in the reservoir for flood control between September and March. Releases through the outlet works are normally determined by the Corps of Engineers. Flows in Los Banos Creek below the dam will not exceed, insofar as possible, 1,000 cubic feet per second. The rate of change in flows shall not exceed 100 cfs during any 4-hour period. Spillway discharges are uncontrolled. During spring and summer, reservoir levels are raised for recreation. Releases from Los Banos Creek Dam are bypassed at the aqueduct through a five–by–six foot evacuation culvert.

At the Little Panoche Creek Detention Dam, no means are provided to regulate the reservoir outflow either over the spillway or through the outlet works. Discharge from the outlet works is uncontrolled and will begin when the reservoir water surface exceeds 602.55 feet. The maximum rate of discharge is 1,040 cfs depending on reservoir head. Discharges over the spillway are also uncontrolled and will begin when the reservoir level exceeds 641.50 feet. The maximum rate of discharge is 3,220 cfs depending on reservoir head. Outflows intersecting the SLC are either bypassed or inputted as outlined above in Standing Order SLFD–OP–91–20E.

Status of the Billie Wright Road sump pump at milepost 74.57LT: This memo advises that pumping of floodwaters from Billie Wright Creek into the SLC was discontinued in March, 1992. Instead, water will be bypassed to the east through a culvert. Water quality monitoring of the Creek, however, will continue.

IV. Floodwater Inflow Characteristics

This chapter describes the characteristics of floodwater inflows. A review of inflow volumes was performed with data collected between 1973 and 1993. A water quality assessment of 1986–1993 data follows with a brief description of water quality thresholds. Concentrations of minerals, minor elements, asbestos, nutrients, organic chemicals, and miscellaneous parameters in floodwater inflows were reviewed in the water quality assessment section.

Inflow Volumes

Floodwater inflow volumes are measured using elevation stream gauging, pump capacity calculations, and visual estimations. Detailed inflow estimation methods are in Table B–2 of Appendix B.

Annual floodwater inflow volumes ranged from 0 to 41,938 af for the 21 years between 1973 to 1993 (Table 3). During this period, floodwater inflows occurred, on average, 14 out of every 100 months. The highest annual inflows were reported for water years 1978 (ca 42,000 af) and 1983 (ca 22,000 af). Little or no inflow was reported for 10 of the 21 years.

Table 3. Floodwater Inflow Volumes from SLC Drain Inlets, Water Years 1973–93. [1]

(in acre–feet)

Water Year	Little Panoche Creek	Cantua Creek	Salt Creek [2]	Arroyo Pasajero	Other D.I.s [3]	Flood Water Pump–Ins[4]	Total
1973	1,144			8,417	12,624 [5]		22,185
1974				1,992			1,992
1975							0
1976							0
1977							0
1978	3,034	1,985	197	35,035		1,687	41,938
1979				412			412
1980	633	489	256	6,259		586	8,223
1981							0
1982		124	5				129
1983	5,029	4,923	598	9,951	121	1,723	22,345
1984			114			313	427
1985						11	11
1986		4,268	333	2,278			6,879
1987							0
1988			15		1		16
1989							0
1990							0
1991		1,890	296			73	2,259
1992		1,531	518		287	548	2,884
1993		4,520	676		125	218	5,539
Total	**9,840**	**19,730**	**3,008**	**64,344**	**13,158**	**5,159**	**115,239**

[1] Inflow data were taken from monthly tables or annual reports provided by San Luis Field Division.
[2] Fresno County.
[3] Includes all other passive inflows from smaller drain inlets (D.I.s)
[4] Includes water pumped in from portable floodwater pumps.
[5] Estimated from precipitation, drain inlets, and miscellaneous pumping.

Most floodwater inflows have come from Arroyo Pasajero, Cantua Creek, Salt Creek, and Little Panoche Creek (Table 3). Prior to 1986, Arroyo Pasajero was the single largest contributor, accounting for about 64 percent of all floodwater inflows (Figure 2). Operating procedures at that site were revised in 1986 to limit inflow volume. Since then, floodwaters from Arroyo Pasajero have not been admitted to the SLC. After 1986, Cantua Creek accounted for about 74 percent of the total measured inflow followed by Salt Creek (14 percent of the total measured inflow) and floodwater pumping (ca 8 percent). Cantua and Salt creeks together have contributed around 88 percent of all floodwater inflows during the last seven years. Floodwaters from Little Panoche Creek have not been admitted to the SLC since 1983 largely due to diminutive rainfall in that watershed (Vansomeren, pers. comm.).

Floodwater inflows occur primarily during the months of January, February, and March (Table 4). Inflows during February accounted for 50 percent of all floodwater inflows between 1973 and 1993 (Figure 3). Inflows during March and January accounted for 32 and 15 percent, respectively, of all floodwater inflows.

When floodwater inflows occur, they usually compose less than ten percent of monthly SLC flows. Dilution ratios were calculated as the ratio of total monthly floodwater inflows to aqueduct flow downstream of all drain inlets at Check 21 between 1973 and 1993. During a few months, ratios exceeded 10 percent and most of those occurred in 1983 (Figure 4). In water year 1983, 27 to 100 percent of the aqueduct was composed of floodwater inflows for four consecutive months.

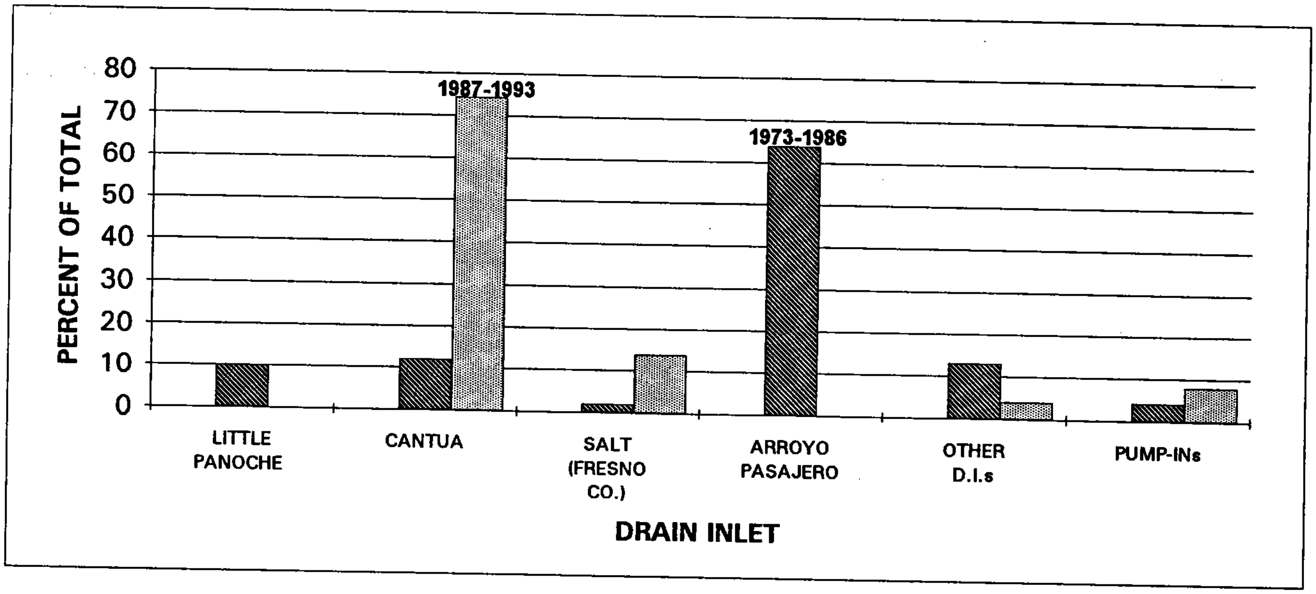

Figure 2. Relative Floodwater Inflow Volumes by Major Drain Inlet in the SLC.

Bars represent percent-of-total inflow volumes from 1973 to 1986 and 1987 to 1993.

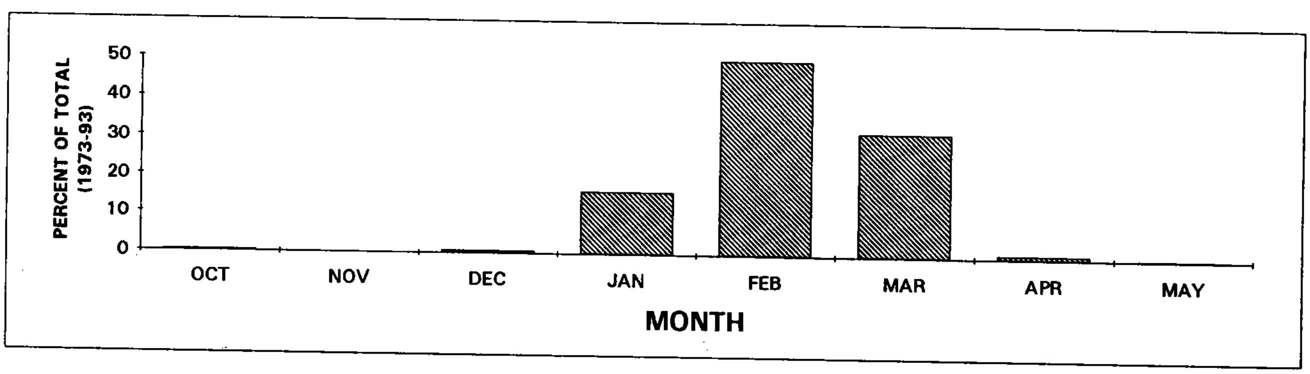

Figure 3. Relative Monthly Floodwater Inflows in Percent.

{[Total inflows per month (1973-93)]/[Total inflows(1973-93] x 100}

Table 4. Monthly Floodwater Inflow Volumes, 1973-1993.
(in acre-feet)

YEAR	ACRE-FEET OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
1973				860	7,318	1,383		
1974				1,992				
1975								
1976								
1977								
1978			340	6,589	23,392	7,748		
1979					412			
1980				218	7,671	334		
1981								
1982							129	
1983			127	5,398	1,973	14,047	579	100
1984	313		114					
1985				11				
1986					3,220	3,323	336	
1987								
1988					7	8	1	
1989								
1990								
1991	4					2,210		
1992				119	2,025	740		
1993					3,328	2,043	168	
TOTAL	**317**	**0**	**581**	**15,187**	**49,346**	**31,836**	**1,213**	**100**

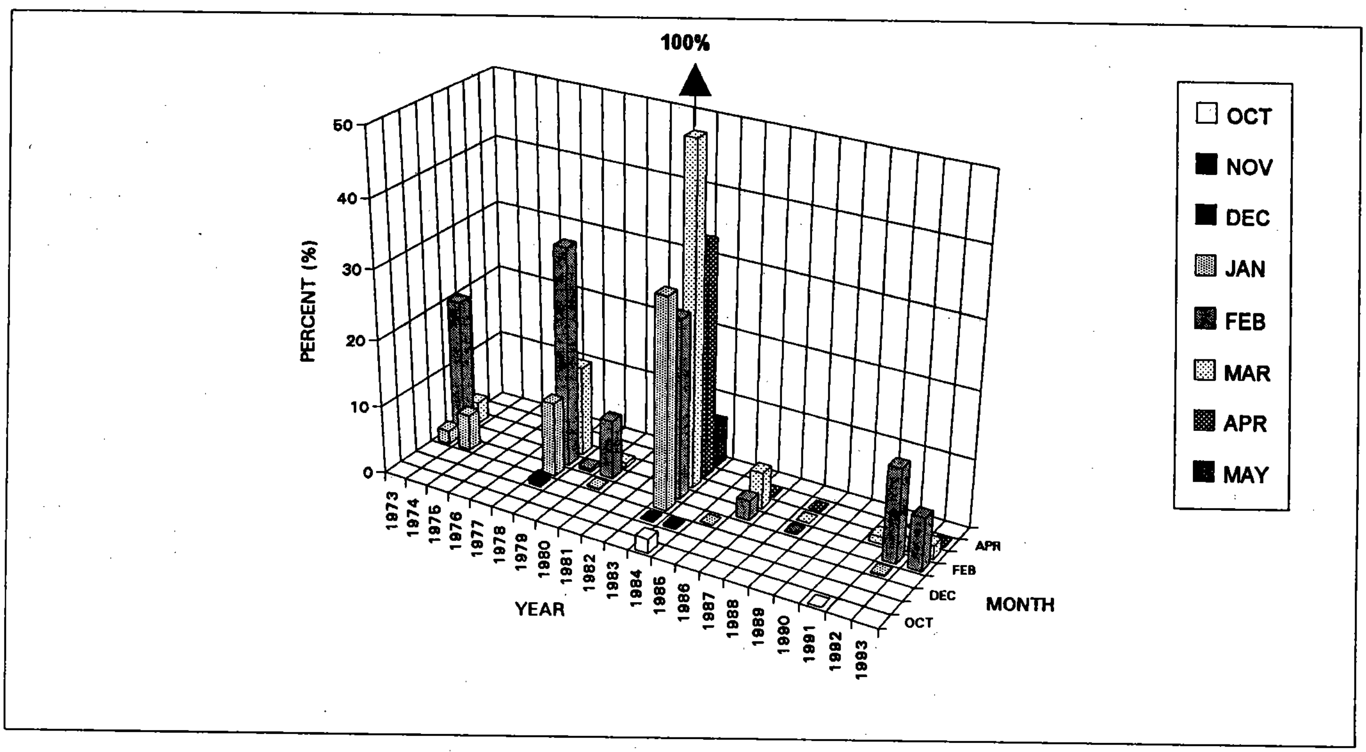

Figure 4. Monthly Floodwater Inflow Dilution Ratios in the SLC.
Percent of monthly flows at Check 21 composed of floodwater inflows.

Water Quality Thresholds

State and federal water quality thresholds listed in Table 5 were used to assess the relative quality of floodwater inflows. A description of their applicability is presented below.

Article 19 Objectives

Article 19 objectives apply to SWP water as stated in the Department's Water Supply Contracts (CDWR 1965). The contracts stipulate that reasonable measures shall be taken to ensure that delivered water contains water quality constituents below the objectives. The three categories of Article 19 objectives are monthly average, 10-year average, and maximum. Floodwater inflow data were compared to the monthly average and maximum objectives to identify parameters of concern to aqueduct water quality. The objectives were only used to compare the relative water quality of floodwater inflows and any parameter exceeding the Article 19 objective does not imply a contract or regulatory violation.

Maximum Contaminant Levels

A Maximum Contaminant Level is the "Maximum permissible level of a contaminant in water which is delivered to any user of a public water system" (U.S.EPA 1994a). MCLs are derived and adopted by the U.S.EPA using the best available scientific data, technical judgement, and an extensive hearing process. State drinking water authorities must adopt MCLs which are at least as stringent as the federal standards; the U.S.EPA's standards are used to determine if public drinking water is in compliance with current regulations. The California Department of Health Services is the primary authority for enforcing compliance with U.S.EPA drinking water standards.

Primary MCLs are achievable levels of drinking water quality designed to protect human heath (U.S.EPA 1994a). They reflect the levels in drinking water that can be safely consumed when accounting for exposure from other sources. Treated drinking water exceeding the primary MCLs presents a risk to the health of humans when continually used for drinking or cooking (40 CFR, Section 644335[a], 8/6/1993). Secondary MCLs are consumer acceptance standards designed to protect taste, odor, color, and other aesthetic aspects of drinking water which do not present a health risk (U.S.EPA 1994a).

Unlike Article 19 objectives, primary and secondary MCLs apply to treated drinking water at the tap or in the distribution system. They do not apply to floodwater inflows or water in the aqueduct. MCLs were used in this report only to gauge relative levels and only when no relevant Article 19 objective existed. Any water quality parameter above a MCL does not imply a contract or regulatory violation.

Water Quality Assessment

The water quality of floodwater inflows was evaluated using data from 1986 through 1993. Categories included minerals, minor elements, nutrients, organic chemicals, and miscellaneous parameters. Data from individual drain inlets in the San Luis Field Division were combined and averaged by watershed. The combined data reflects waters influenced by watersheds that are alike in their geological make-up. Averages were compared to WQTs to assess relative concentrations only and any exceedences do not imply water quality impacts. Methods of collection, analysis, and quality control are presented in Appendix B. Complete databases are in Appendix C.

Minerals

Minerals analyzed include the cations: calcium, magnesium, sodium, and potassium and the anions: sulfate, chloride, boron, nitrate, and fluoride. Conventional parameters such as salinity, pH, and alkalinity were also included here. Minerals data exist for 14 of the 34 watersheds including all major contributing watersheds.

Table 5. State and Federal Water Quality Thresholds.

Water Quality Parameters	CDWR Article 19 Objectives				Maximum Contaminant Level (MCL) Drinking Water Standards			
					CDHS		U.S. EPA	
	Units	Monthly	10-Year	Max.	Primary	Secondary	Primary	Secondary
Minerals								
Specific Conductance	uS/cm					900–1,600–2,200 [a]		
Hardness (as $CaCO_3$)	mg/l	180	110					
pH	pH							6.5–8.5
Total Dissolved Solids	mg/l	440	220			500–1,000–1,500 [a]		500
Turbidity	NTU				1 [d]	5		
Boron	mg/l	0.6						
Chloride	mg/l	110	55			250–500–600 [a]		250
Fluoride	mg/l			1.5	1.4–2.4 [c]		4	2.0
Sodium	%	50	40					
Sulfate	mg/l	110	20			250–500–600 [a]		250
Minor Elements								
Arsenic	ug/l			50	50		50	
Aluminum	ug/l				1,000			50–200
Barium	ug/l				1,000		2,000	
Cadmium	ug/l				10		5	
Chromium (total)	ug/l				50		100	
Copper	ug/l			3,000		1,000		1,000
Iron	ug/l			300 [b]		300		300
Lead	ug/l			100	50			
Magnesium	ug/l			125,000				
Manganese	ug/l			300 [b]		50		50
Mercury	ug/l				2		2	
Selenium	ug/l			50	10		50	
Silver	ug/l				50		50	
Zinc	ug/l			15,000		5,000		5,000
Asbestos	MFL [e]						7	
Nutrients								
Nitrate	mg/l				45 (as NO_3)		10 (as N)	
Nitrite	mg/l						1 (as N)	
Nitrate + Nitrite	mg/l						10 (as N)	
Organic Chemicals								
Pentachlorophenol	ug/l						1	

[a] *Recommended – Upper – Short term*
[b] *Iron + Manganese*
[c] *Varies with the annual average maximum daily air temperature.*
[d] *Monthly average. Levels up to, and including, 5 units may be allowed under certain situations.*
[e] *MFL = Million Fibers per Liter of fibers greater than 10 microns in length.*

Salinity: Two measurements of salinity are total dissolved solids and electrical conductivity, or specific conductance. Both were reported above WQTs in over half the watersheds sampled (Table 6). TDS ranged from 57 to 6,488 mg/l with a median of 713 mg/l. Nine of 14 watersheds sampled had TDS values exceeding the Article 19 objective monthly average of 440 mg/l. EC in floodwater inflows ranged from 41 to 8,150 uS/cm with a median of 1,098 uS/cm. Eight of the 14 watersheds sampled had ECs averaging greater than the recommended secondary MCL of 900 uS/cm. Floodwaters from both major contributing watersheds had TDS and EC levels above the WQTs. Elevated salts originate from leaching of natural geologic formations in the Diablo Range.

The variability of EC measurements (expressed as coefficient of variation) within individual watersheds ranged from 5 to 91 percent (Table 6). Most COV values were below 50 percent, indicating that the high salinity measurements were relatively consistent (for rainfall runoff water quality) within each watershed.

The salt content of floodwaters did not show any strong intraseason trends such as a first flush effect. A first flush effect is when surface evaporites (salts) build up during the summer and are subsequently flushed from the watershed during the first few storms of the season. Past studies suggest that certain Diablo Range streams exhibit a first flush effect (Presser et al. 1990). Several factors could be attributed to the lack of correlation between peak salinity and early season floodwater inflows. A first flush effect would be less apparent during the middle of the rainy season when most inflows to the SLC occur. Evaporites that were solubilized from early season rainfall percolate with water into the ground and become inaccessible to future runoff events. Further, floodwaters are ponded, to some extent, prior to draining into the aqueduct. Ponded water composites the changing water quality characteristics of floodwaters and would tend to diminish any salinity spikes. Another influencing factor may be stream flow velocity which has been inversely correlated with TDS in certain watersheds (Davis, 1961). Therefore, the lack of a strong seasonal first flush effect reduces the importance of sampling early season floodwater inflows to capture peak salt levels.

pH and Alkalinity: Floodwaters were alkaline with a pH range of 6.6 to 8.2 and a median of 7.6 (Table 6). The pH was explained, in part, by alkalinity measurements ranging between 16 and 221 mg/l with a median of 95 mg/l (as $CaCO_3$). Alkalinity typically reflects the weak buffering activity of bicarbonate which is controlled in natural waters by dissolved carbon dioxide and carbonate containing minerals. The alkalinity of floodwater inflows is augmented from naturally occurring carbonate minerals prevalent throughout the Diablo Range (Davis 1961).

Cations: Calcium levels in floodwater inflows ranged from 2 to 567 mg/l with a median of 77 mg/l (Table 6). The concentration of calcium in floodwaters was usually higher than that of magnesium and ranged above 100 mg/l in nearly half the watersheds sampled. The exception was Billie Wright Creek where magnesium and calcium averages were very similar, 224 mg/l versus 268 mg/l, respectively. Calcium is the most common alkaline earth element in natural waters and originates largely from gypsum ($CaSO_4$) and $CaCO_3$ deposits in the Diablo Range (Davis 1961). Magnesium in floodwater inflows also originates from certain geological formations and ranged in concentration from 1 to 224 mg/l with a median of 24 mg/l.

Calcium and magnesium levels together represent the hardness of water. Hardness concentrations in floodwater inflows ranged from 9 to 1,670 mg/l with a median of 289 mg/l (as $CaCO_3$; Table 6). Floodwaters from 80 percent of the watersheds sampled exhibited hardness levels above the Article 19 objective monthly average of 180 mg/l. Floodwaters from both major contributing watersheds contained hardness levels above the WQT.

Sodium was frequently the dominant cation in floodwater inflows and ranged from 1 to 1,078 mg/l with a median of 93 mg/l (Table 6). Sodium is an inherent constituent of connate waters and marine sediments within the Diablo Range (Davis 1961). Four samples were analyzed for potassium which ranged from 4 to 18 mg/l with a median of 12 mg/l.

Table 6. Mineral Analyses in Floodwaters Draining to the Aqueduct in the Study Area. [a]

I.D. #	Watershed [b] Name & Milepost Range	Date		Lab pH	Lab EC	Hardness (as $CaCO_3$)	Tot. Alk. (as $CaCO_3$)	Ca	Mg	Na	K	SO_4	Cl	NO_3 [c]	Fl	B	TDS
						Average Concentration, MG/L (filtered)											
2	Crow Creek Hills Group, Milepost: 50.14	3/26/93		6.6	41	9	16	2	1	1		2	1	0.5	< 0.1	0.1	57
9	O'Neill Forebay Drainage, North, Milepost: 66.51	4/21/93		7.9	658	***196***	132	54	15	51		79	68	< 0.1	0.1	0.4	406
San Luis Canal																	
12	Billie Wright Drainage, Milepost: 74.57	1/18/88–1/5/93	Average	8.0	***8,150***	***1,590***	221	268	***224***	1,078		***1,990***	***1,194***	***51***	0.4	***4.0***	***6,488***
			Cov. %	1.3	32	31	10	27	34	36		31	45	50	25	29	36
			# Samples	3	3	2	2	2	2	2		2	2	2	2	2	3
16	Ortigalita Creek Group, Milepost: 82.67	2/27/93		8.0	723	***196***	140	42	22	72		***130***	54	8	0.2	***0.7***	***462***
18	Laguna Seca Creek, Milepost: 89.67	10/3/90 or 10/3/91		7.2	***3,600***	***1,670***	127	567	62	308		***1,670***	***259***		0.2	***2.8***	***3,190***
21	Little Panoche Creek, Milepost: 96.56	2/28/93		8.2	***1,130***	***243***	166	56	25	136		109	***189***	6	0.3	***3.0***	***658***
25	Monocline Ridge Group, Milepost 116.38–118.17	1/9/92–3/28/91	Average	7.6	***4,665***	***1,435***	100	409	101	686	18	***2,400***	96	***49***	0.4	***0.8***	***4,110***
			Cov. %	1.8	3	11	14	13	7	4		3	14	6	25	20	5
			# Samples	2	2	2	2	2	2	2	1	2	2	2	2	2	2
28	Cantua Creek Group, Milepost: 134.81	2/28/91–2/19/93	Average	8.0	***1,179***	***481***	140	116	47	85	12	***459***	16	6	0.3	0.4	***883***
			Cov, %	1.9	27	36	37	59	21	25		45	50	38	38	17	36
			# Samples	7	7	7	7	7	7	7	2	7	7	7	7	7	7
29	Salt Creek Group, Fresno County, Milepost: 134.92–138.24	2/28/91–2/19/93	Average	7.5	***1,179***	***334***	59	99	21	101		***403***	49	10	0.3	***0.7***	***768***
			Cov, %	1.9	50	71	21	73	66	50		70	54	37	62	57	59
			# Samples	10	10	10	10	10	10	10		10	10	10	10	10	10
30	Jorden Group, Milepost: 138.95–148.95	3/20/91–1/14/93	Average	7.4	***1,601***	***602***	60	184	35	135		***705***	76	8	0.4	***1.4***	***1,253***
			Cov, %	1.9	49	48	43	47	55	65		53	846	25	54	72	52
			# Samples	6	6	6	6	6	6	6		6		6	6	6	6
31	Ford Group, Milepost: 143.12	3/24/92		7.5	***2,060***	***803***	63	254	41	173		***968***	45	6	0.2	***1.9***	***1,710***
32	Skunk Hollow, Milepost: 152.20	1/16/93		7.0	175	42	39	10	4	17		29	4	7	0.2	< 0.1	106
33	Arroyo Pasajero, Milepost: 158.36–163.69	3/20/91–1/16/93	Average	7.7	574	***159***	89	35	18	54		***163***	14	5	0.4	0.4	366
			Cov, %	1.8	2	4	21	4	14	3		5	0	32	50	0	2
			# Samples	2	2	2	2	2	2	2		2	2	2	2	2	2
34	Kettleman Hills Group, Milepost: 167.78–169.37	12/3/90–2/19/93	Average	7.3	279	57	60	12	7	34	4	16	36	4	0.2	0.2	173
			Cov, %	1.4	91	81	36	64	98	90		122	148	60	58	33	74
			# Samples	4	4	4	4	4	4	4	1	4	4	4	4	4	4
			Median	7.6	1,098	289	95	77	24	93	12	283	52	6	0.2	1	713
			Minimum	6.6	41	9	16	2	1	1	4	2	1	<0.1	0.1	0.1	57
			Maximum	8.2	8,150	1,670	221	567	224	1,078	18	2,400	1,194	51	0.4	4	6,488
			Total # of Samples	41	41	40	40	40	40	40	4	40	40	39	40	40	41
			Total # of watersheds above WQTs [d]	N.A.	8	11	N.A.	N.A.	1	N.A.	N.A.	9	3	2	0	8	9
			% of watersheds above WQTs [e]	N.A.	57	79	N.A.	N.A.	7	N.A.	N.A.	64	21	15	0	57	64

a Concentration values in bold italic exceed one or more water quality thresholds.
b Shaded watersheds and concentration values highlight major contributing watersheds.
c As N_{O3}
d WQT = Water Quality Threshold.
e (Number of watersheds above WQT) / (Number of watersheds sampled) in percent.

Anions: Sulfate concentrations in floodwater inflows ranged from 2 to 2,400 mg/l with a median of 283 mg/l (Table 6). Concentrations were above the Article 19 objective monthly average of 110 mg/l in over half the watersheds sampled. Floodwaters from both major contributing watersheds contained sulfate levels above the WQT. High sulfate levels originate from marine sedimentary deposits and connate springs (Davis 1961).

Chloride levels in floodwater inflows were usually below those of sulfate. Concentrations ranged from 1 to 1,194 mg/l with a median of 52 mg/l (Table 6). Three of 14 watersheds sampled contained chloride levels (189 to 1,194 mg/l) above the Article 19 objective monthly average of 110 mg/l. Floodwaters from Little Panoche Creek and the Kettleman Hills Group had levels of chloride that were higher than corresponding sulfate concentrations. Diablo Range waters where the chloride/sulfate ratio is greater than one indicate influence from connate springs (Davis 1961).

Fluoride levels in floodwater inflows were well below the Article 19 objective maximum of 1.5 mg/l and ranged from 0.1 to 0.4 mg/l with a median of 0.2 mg/l (Table 6). Nitrate levels (as NO_3) ranged from <0.1 to 51 mg/l with a median of 6 mg/l. Nitrate levels from Billie Wright Creek and the Monocline Ridge Group (51 and 49 mg/l, respectively) exceeded the primary MCL of 45 ug/l (a more complete description of nutrients is presented below). Boron levels ranged from <0.1 to 4.0 mg/l with a median of 0.07 mg/l. The Article 19 objective monthly average for boron (0.6 mg/l) was exceeded in over half the watersheds sampled. Floodwaters from one major contributing watershed (Salt Creek) had a boron average above the WQT.

Minor Elements

Minor elements include metals (aluminum, barium, cadmium, copper, chromium, lead, manganese, mercury, silver, zinc) as well as metalloids (arsenic, selenium). Fifteen of the 34 watersheds have been monitored for minor elements and seven of the 15 were sampled more than once. Minor elements were not universally elevated in floodwater inflows. Four elements exceeded the WQTs and the frequency of those exceedences was rare.

Selenium concentrations in floodwater inflows ranged from <1 to 182 ug/l with a median of 6 ug/l (Table 7). Selenium exceeded the Article 19 objective maximum of 50 ug/l in two of the 15 watersheds sampled. Selenium was found in Billie Wright Creek at 182 ug/l (COV=35 percent, n=6) and in floodwaters from the Monocline Ridge Group at 145 ug/l (COV=6 percent, n=2). High selenium levels are expected in runoff from the Monocline Ridge area (watershed I.D. Nos. 24–26) because the soil there contains very high levels of selenium (Gillium et al. 1989). Water in Billie Wright Creek (watershed I.D. No. 12) appears to be strongly influenced by connate springs, however, pumping from this site has ceased and no longer poses a threat to the aqueduct.

Arsenic was detected at relatively low levels in all watersheds sampled. Concentrations ranged between 1 and 14 ug/l with a median of 2 ug/l (Table 7). None were above the Article 19 objective of 50 ug/l.

The common earth metals iron, manganese, and aluminum were detected at low to moderate levels in floodwater inflows from most watersheds sampled (Table 7). Iron averages ranged from 5 to 849 ug/l with a median of 31 ug/l. The Article 19 objective maximum of 300 ug/l was exceeded in floodwaters from the Crow Creek Hills Group (watershed I.D. No. 2; 356 ug/l) and the Kettleman Hills Group (watershed I.D. No. 34; 849 ug/l). Manganese levels ranged from <5 to 790 ug/l with a median of 18 ug/l. One exceptionally high manganese value of 790 ug/l was detected in floodwaters from the Laguna Seca Group and was above the Article 19 objective maximum of 300 ug/l. Aluminum averages ranged from 1 to 1,418 ug/l with a median of 23 ug/l. Samples collected from the Kettleman Hills Group (watershed I.D. No. 34) had an average aluminum concentration of 1,418 ug/l which was above the primary MCL of 1,000 ug/l.

Table 7. Minor Element Analyses in Floodwaters Draining to the Aqueduct in the Study Area. [1]

Watershed [2] I.D. #	Name & Milepost Range	Date		Average Concentration, UG/L (filtered [3]) Al	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Se	Ag	Zn
2	Crow Creek Hills Group, Milepost: 50.14	3/26/93		1	1	< 50	< 5	< 5	< 5	***356***	< 5	5	< 1	< 1	< 5	5
9	O'Neill Forebay Drainage, North, Milepost: 66.51	4/21/93		< 10	2	159	< 5	< 5	11	26	< 5	8	< 1	1	< 5	6
San Luis Canal																
12	Billie Wright Drainage, Milepost: 74.57	3/6/87–1/15/93	Average	3	<1000	< 5	< 5	9	20	< 5	< 5	25	*< 1	***182***		29
			Cov, %	35		0	0	55	45	0	0	64	0	35		133
			# Samples	5		2	5	5	5	5	5	5	4	6		5
16	Ortigalita Creek Group, Milepost: 82.67	2/27/93		17	2	73	< 5	< 5	< 5	38	< 5	7	< 1	2	< 5	5
18	Laguna Seca Creek, Milepost: 89.67	10/3/90			4	< 280	< 5	< 5	< 5	53	< 5	***790***	< 1	7	< 5	9
21	Little Panoche Creek, Milepost: 96.56	2/28/93		< 10	1	84	< 5	< 5	< 5	10	< 5	< 5	< 1	< 1	< 5	5
25	Monocline Ridge Group, Milepost: 116.38–118.17	3/28/91–1/9/92	Average	11	2	100	< 5	< 5	9	11	< 5	61	< 1	***145***	< 5	10
			Cov, %		33			0	11	43	0	22	0	6		10
			# Samples		2			2	2	2	2	2	2	2		2
	Arroyo Ciervo Group, Milepost: 119.63	10/30/87		7	14	<1000	< 5	< 5	7	16	< 5	13	*< 1	7		11
28	Cantua Creek Group, Milepost: 134.81	2/28/91–2/19/93	Average	29	2	152	< 5	6	6	31	< 5	18	< 1	8	< 5	7
			Cov, %	79	34	71	0	44	27	115	0	95	0	48	0	50
			# Samples	6	7	6	6	7	7	7	7	7	7	7	6	7
29	Salt Creek Group, Fresno County, Milepost: 134.92–138.24	2/28/91–2/19/93	Average	86	3	162	< 5	< 5	6	75	< 5	17	< 1	6	< 5	8
			Cov, %	106	57	59	0	0	36	85	0	91	0	67	0	92
			# Samples	6	10	6	6	10	10	10	10	10	10	10	6	10
30	Jorden Group, Milepost: 138.95–140.95	3/20/91–2/8/93	Average	30	2	171	< 5	< 5	5	23	< 5	22	< 1	10	< 5	6
			Cov, %	79	29	67	0	0	0	119	0	64	0	55	0	14
			# Samples	5	6	5	5	6	6	6	6	6	6	6	5	6
31	Ford Group, Milepost: 143.12	3/24/92			3			< 5	22	5	< 5	22	< 1	9		5
32	Skunk Hollow, Milepost: 152.20	1/16/93		116	4	< 50	< 5	< 5	< 5	228	< 5	< 5	< 1	< 1	< 5	5
33	Arroyo Pasajero, Milepost: 158.36–158.39	2/28/91–1/16/93	Average	29	2	64	< 5	< 5	6	40	< 5	26	< 1	2	< 5	15
			Cov, %	40	53	19	0	0	24	42	0	101	0	19	0	62
			# Samples	2	2	2	2	2	2	4	2	2	2	4	2	4
34	Kettleman Hills Group, Milepost: 167.78–169.37	1/16/93–2/19/93	Average	***1,418***	5	< 5	< 5	< 5	6	***849***	< 5	21	< 1	< 1	< 5	6
			Cov, %	88	9	0	0	0	30	53	0	27	0	0	0	24
			# Samples	3	3	3	3	3	3	3	3	3	3	3	3	3
			Median	23	2	126	< 5	< 5	6	31	< 5	18	< 1	6	< 5	6
			Minimum	1	1	5	< 5	< 5	5	5	< 5	< 5	< 1	< 1	< 5	5
			Maximum	1,418	14	171	< 5	6	22	849	< 5	790	< 1	182	< 5	29
			Total # of Samples	29	43	30	33	43	43	47	43	43	42	46	29	45
			Total # of watersheds above WQTs [4]	1	0	0	0	0	0	2	0	1	0	2	0	0
			% of watersheds above WQTs [5]	8	0	0	0	0	0	14	0	7	0	14	0	0

[1] Concentration values in bold italic exceed one or more water quality threshold.
[2] Shaded watersheds and concentration values highlight major contributing watersheds.
*[3] All samples are reported as filtered except for mercury values identified as *< 1.*
[4] WQT = Water Quality Threshold.
[5] (Nubmer of watersheds above WQT) / (Number of watersheds sampled) in percent.

The high iron and aluminum levels measured in floodwaters from the Kettleman Hills Group watershed were not consistent with levels detected in other Diablo Range floodwaters. Both elements were present at high levels in the same samples, indicating a similar source. Analyses were performed on three samples collected at three different drain inlets (mileposts 167.78, 168.62, and 169.37). Aluminum was reported at 3,100 ug/l, 124 ug/l, and 1,030 ug/l and coincided with respective iron levels of 1,200 ug/l, 208 ug/l, and 1,140 ug/l. The concentration of these metals was usually lower in other Diablo Range watersheds (1 to 116 ug/l aluminum and 10 to 356 ug/l iron). Furthermore, organic carbon (40.9 mg/l), total suspended solids (5,150 mg/l), and nitrate (49 mg/l as NO_3) were also detected at peak levels in this watershed. The unusually elevated levels suggest that the source or sources are anthropogenic in origin. Further, the chloride/sulfate ratio in floodwaters from this watershed was greater than one which indicates influence from connate water. Oil production wells and landfills are both situated within this watershed (see discussion in the Watershed Description section).

Lead, silver, and cadmium were not detected in floodwater inflows (Table 7). This was to be expected since all three are not very soluble in water. Insolubility is compounded by high suspended solids which can facilitate their removal during filtration. Total (unfiltered) and dissolved mercury levels were also below the reporting limit of <1 ug/l. Chromium was detected once in floodwaters from the Cantua Creek Group at 6 ug/l. All other chromium levels were below the reporting limit of <5 ug/l.

Copper levels in floodwater inflows ranged from <5 to 22 ug/l with a median of 6 ug/l (Table 7). Zinc averages ranged from 5 to 29 ug/l with a median of 6 ug/l. All copper and zinc levels were below WQTs.

Barium levels in floodwater inflows ranged from <5 to 171 ug/l with a median of 126 ug/l (Table 7). The barium primary MCL of 1,000 ug/l was not exceeded in any of the floodwater samples.

Asbestos

Floodwaters are periodically sampled for asbestos by staff of the San Joaquin Field Division and San Joaquin District. Asbestos data for 1991 through 1993 are presented in Table 8. Analyses prior to 1991 were not included because they were reported as total number of fibers greater than five microns in length and were incomparable to the present method which measures asbestos fibers greater than 10 microns in length. Asbestos originates from the erosion of natural serpentine soils and runoff from inactive mines.

Salt and Cantua creeks are sources of asbestos to the aqueduct although complete assessment was hindered by elevated detection limits caused by high turbidity levels. Three of 12 samples contained asbestos at or above the detection limit (Table 8). In Cantua Creek, asbestos was detected twice at 950 and 380 million fibers per liter (the 380 MFL level was at the detection limit). One sample from the Salt Creek Group contained 1,900 MFL. Detection limits for all floodwater samples ranged from <5.3 to <1,300 MFL. Detection limits are raised when sample waters are high in suspended solids. Suspended solids are trapped along with asbestos during filtration and physically occlude individual fibers from being seen and counted (Chatfield and Dillon 1983). This results in analyses reported below detection even though asbestos may be present. Asbestos detection limits were also high in floodwaters ponded at Arroyo Pasajero although none of this water was admitted to the aqueduct.

Table 8. Asbestos Concentrations in Floodwaters Draining to the California Aqueduct in the Study Area.

Watershed				
I.D. #	Name	Sample Date	Concentration MFL [1]	Detection Limit
28	Cantua Creek Group	3/4/91	ND	11
		3/4/91[3]	ND	5.3
		1/16/93	950	320
		2/19/93	380	380
29	Salt Creek Group	3/4/91	ND	110
		1/16/93	ND	1,300
		2/19/93	1,900	480
	Milepost 137.80 [2]	3/20/91	ND	210
		3/20/93[3]	ND	210
33	Arroyo Pasajero [4]	3/20/91	ND	210
		3/20/91[3]	ND	210
		3/17/93	ND	64

[1] *Million Fibers per Liter of fibers >10 microns in length. ND = not detected.*
[2] *Pump-in from portable pump at milepost 137.80.*
[3] *Replicate.*
[4] *Water sampled from the ponding area weir although none was admitted to the aqueduct.*

Miscellaneous Parameters

Several water quality parameters have been lumped together as miscellaneous and include total organic carbon, bromide, total suspended solids, and volatile suspended solids. Samples analyzed for at least one miscellaneous parameter have been collected from ten of the 34 watersheds. Floodwaters from the major contributing watersheds have been characterized with at least one sample.

Average TSS levels in floodwater inflows ranged from 22 to 5,150 mg/l with a median of 265 mg/l (Table 9). Although no WQT exists for TSS, measurements in the aqueduct commonly range between 5 and 30 mg/l. Some of the highest TSS levels were detected in floodwaters from Salt Creek (Fresno County; watershed I.D. No. 29) where the average was greater than 2,800 mg/l (COV=147 percent, n=8). The ponding capacity at the Cantua Creek drain inlet is greater than Salt Creek's and is reflected in the lower (but still high) TSS average of 984 mg/l (COV=82 percent, n=5). The high TSS levels are a result of erosional materials carried across alluvial fans within high velocity floodflows. Sediments discharged to the aqueduct increase dredging maintenance and water treatment effort.

Total organic carbon levels in floodwater inflows ranged from 1.0 to 40.9 mg/l with a median of 9.1 mg/l (Table 9). Both major contributing watersheds have been sampled for TOC. Total organic carbon in natural waters reflects the sum of organic detritus and it's complex breakdown products. The concentration of TOC in floodwaters is high compared to the TOC content of aqueduct water. Total organic carbon levels at Banks Pumping Plant in the south Delta typically range from 3 to 9 mg/l with an average of about 5 mg/l.

Total organic carbon is directly correlated with the undesirable formation of disinfection byproducts during the water treatment process. Disinfection byproducts include chloroform, bromoform, bromodichloromethane, and dibromochloromethane and are collectively known as trihalomethanes. The term referring to the total trihalomethane concentration after simulated treatment is called total trihalomethane formation potential or TTHMFP. There are no data on

Table 9. Miscellaneous Water Quality Parameters in Floodwaters Draining to the Aqueduct in the Study Area. [1]

Watershed				Average Concentration, MG/L			
I.D. #	**Name & Range**	**Date**		**TOC**	**Bromide**	**TSS**	**VSS**
7	Quinto Creek, Milepost: 62.01	1/6/86		1.0			
San Luis Canal							
16	Ortigalita Creek Group, Milepost: 82.12–82.67	7/23/92–2/27/93	Average	8.9	0.34	265	23
			Cov, %			8	16
			# Samples	1	1	2	2
21	Little Panoche Creek, Milepost: 96.57	2/28/93				88	8
25	Monocline Ridge Group, Milepost: 115.43–118.17	3/28/91–1/18/93	Average	13.3	0.77	39	6
			Cov, %	55		52	8
			# Samples	3	1	3	3
28	Cantua Creek Group, Milepost: 134.81		Average	15.4	0.06	984	75
			Cov, %	39		82	75
			# Samples	5	1	5	5
29	Salt Creek Group, Fresno County, Milepost: 135.90–138.00	3/2/91–2/19/93	Average	13.9	0.16	2,844	195
			Cov, %	67	40	147	131
			# Samples	8	4	8	8
30	Jordan Group, Milepost: 138.95–140.95	3/20/91–2/8/93	Average	9.1	0.24	196	20
			Cov, %	33	51	139	106
			# Samples	8	5	8	8
31	Ford Group, Milepost: 143.12	3/24/92				22	6
33	Arroyo Pasajero, Milepost: 158.36–158.37	3/20/90–1/16/93	Average	7.4	0.03	67	9
			Cov, %	11		22	22
			# Samples	3	2	3	3
34	Kettleman Hills Group, Milepost: 167.78	2/19/93		40.9		5,150	430
	Other (City of Hesperia), Milepost: 398.00	1/7/93		11.9	0.01	489	57
			Median	9.1	0.16	265	23
			Minimum	1	0.01	22	6
			Maximum	40.9	1	5,150	430
			Total # of Samples	9	7	10	10
			Total # of watersheds above WQTs [2]	N.A.	N.A.	N.A.	N.A.
			% of watersheds above WQTs [3]	N.A.	N.A.	N.A.	N.A.

[1] *Shaded watersheds and concentration values highlight major contributing watersheds*
[2] *WQT = water quality threshold.*
[3] *(Number of watersheds above WQT)/(Number of watersheds sampled) in percent.*

TTHMFP in floodwater inflows. However, compared to the relationship between TOC and TTHMFP in the aqueduct, the TTHMFP in floodwaters could be high. At Banks Pumping Plant, TOC concentrations of 3 and 10 mg/l corresponded to TTHMFP values of 2.50 and 8.55 μmoles/ℒ, respectively. Most floodwater inflows contained TOC at 7 to 15 mg/l and may exhibit correspondingly high TTHMFP levels.

Bromide levels in floodwater inflows ranged from 0.01 to 0.77 mg/l with a median of 0.16 mg/l (Table 9). Similar to chloride, bromide is an halogen and another measure of saltwater influence. Floodwater bromide levels were usually lower than those found in the aqueduct (0.335 to 0.392 mg/l). The major contributing watersheds have been sampled at least once for bromide.

Nutrients

Floodwater inflows from five of the 34 watersheds and both major contributing watersheds have been sampled for nutrients. Nutrient analyses include nitrate plus nitrite ($NO_3 + NO_2$ as N), total and dissolved phosphate, ammonia, and organic nitrogen. Nutrients can originate from crop and animal agriculture. However, based on existing data, these sources do not appear to be resulting in universally elevated nitrogen levels.

Table 10. Nutrient Analyses in Floodwaters Draining to the Aqueduct in the Study Area. [1]

Watershed I.D. #	Name & Range	Date		Average Concentration, MG/L: Organic Nitrogen	NO_3+NO_2 [2]	Dissolved NH_4	Dissolved PO_4	Total PO_4
12	Billie Wright Drainage, Milepost: 74.57	4/14/92		0.7	5.3	0.02	0.04	0.06
28	Cantua Creek Group, Milepost: 134.86	2/11/92		4.2	0.82	0.15	0.07	2.30
29	Salt Creek Group, Fresno County, Milepost: 136.00	2/11/92–12/7/92	Average	0.9	2.1	0.16	0.41	1.3
			Cov, %	22	0	31	10	8
			# Samples	2	2	2	2	2
31	Ford Group, Milepost: 143.12	3/24/92		1.4	1.2	0.08	0.11	0.21
	Other (City of Hisperia), Milepost: 398.00	1/7/93		1.8	0.3	0.12	0.28	2.50
			Median	1.4	1.2	0.02	0.11	1.3
			Minimum	0.7	0.3	0.12	0.04	0.06
			Maximum	4.2	2.1	0.41	0.41	2.5
			Total # of Samples	5	5	5	5	5
			Total # of watersheds above WQTs [3]	N.A.	0	N.A.	N.A.	N.A.
			% of watersheds above WQTs [4]	N.A.	0	N.A.	N.A.	N.A.

[1] *Shaded watersheds and concentration values highlight major contributing watersheds*
[2] *As Nitrogen.*
[3] *WQT = water quality threshold.*
[4] *(Number of watersheds above WQT)/(Number of watersheds sampled) in percent.*

The NO_3 + NO_2 levels in floodwater inflows ranged from 0.3 to 5.3 mg/l with a median of 1.2 mg/l (Table 10). All analyses were below the federal primary MCL of 10 mg/l. Dissolved ammonia ranged from 0.02 to 0.16 mg/l with a median of 0.12 mg/l. Organic nitrogen concentrations ranged from 0.7 to 4.2 mg/l with a median of 1.4 mg/l. Nitrogen products are undesirable because they can stimulate algal growth. Excessive algal growth in the aqueduct can clog conveyance structures, increase maintenance cost and effort, and may generate taste and odor compounds.

More extensive measurements of nitrate (as NO_3) are in Table 6. Nitrate concentrations ranged from <0.1 to 51 mg/l (Table 6). The State primary MCL of 45 mg/l was exceeded in floodwaters from Billie Wright Creek (51 mg/l) and the Monocline Ridge Group (49 mg/l). Neither of the high nitrate levels came from the major contributing watersheds nor from watersheds with known livestock operations. A sample collected downstream from the Harris Ranch cattle yard (Ford Group) contained 6 mg/l nitrate (as NO_3). No nutrients data exists for floodwater inflows downstream from Cal-Star dairy. Both facilities hold their site runoff in ponding areas (see discussion in Watershed Description section).

Total and dissolved phosphate levels ranged from 0.04 to 2.50 mg/l with medians of 1.3 and 0.11 mg/l, respectively (Table 10). Phosphate is also a biostimulant and can promote the growth of algae in aquatic systems.

Organic Chemicals

Organic chemicals were analyzed in floodwater inflows from 12 of the 34 watersheds. Both major contributing watersheds have been sampled. A typical organic chemical analysis will include one or more U.S.EPA methodology scans of major chemical classifications such as purgeable organics, chlorinated organic pesticides, organic phosphorus pesticides, chlorinated and phenoxy acid herbicides, carbamates, and miscellaneous pesticides such as glyphosate.

Most of the organic chemicals detected were pesticides. Pesticides in floodwaters probably originated from lands commercially farmed west of the SLC. Pesticides were detected in approximately half of the 32 samples collected; there were no detectable levels of pesticides in the other half.

Table 11. Organic Chemical Analyses in Floodwaters Draining to the Aqueduct in the Study Area.[1]

Watershed I.D. #	Watershed Name	Milepost	Date	Time	Chemical Name	Concentration UG/L
9	O'Neill Forebay Drainage, North	66.51	4/21/93	910	*Unknowns* Based on internal standard	2.00
					Diazinon	0.61
San Luis Canal						
12	Billie Wright Drainage	74.57	4/14/92	600		*None Detected
16	Ortigalita Creek Group	82.67	2/27/93	1320		*None Detected
			10/3/90	600	TRIS PHOSPHATE	1.30
21	Little Panoche Creek	96.57	2/28/93	1230		*None Detected
25	Monocline Ridge Group	115.43	1/14/93	1330		*None Detected
			1/18/93	1200		*None Detected
		116.38	1/9/92	1400	Dacthal (DCPA)	0.20
28	Cantua Creek Group	134.81	2/16/86	2120		*None Detected
			3/2/91	1000	Diuron	0.09
					TRIS PHOSPHATE	0.20
				1015	Diuron	0.80
			1/8/93	930	Cyanizine	0.40
			2/8/93	1700	Cyanazine	0.30
			2/19/93	1030	Pentachlorophenol (PCP)	0.40
		134.86	2/11/92	1220	Dacthal (DCPA)	0.04
					Cyanazine	0.70
29	Salt Creek Group (Fresno Co.)	134.92	2/19/93	1115	Diazinon	0.06
					Methidathion	0.02
					Dacthal (DCPA)	0.40
					Cyanazine	0.87
		136.00	2/15/86	140		*None Detected
			2/16/86	2200		*None Detected
			2/11/92	1245	Diuron	0.80
					Dacthal (DCPA)	0.60
					Cyanazine	0.40
			12/7/92	1430	Dacthal (DCPA)	2.20
					Cyanazine	13.00
			2/19/93	1200		*None Detected
		138.14	2/13/92	1400	Diuron	0.08
					Dacthal (DCPA)	0.10
					Cyanazine	2.00
		138.24	2/13/92	1300	Dacthal (DCPA)	0.10
					Cyanazine	0.80
30	Jordan Group	138.96	2/13/92	1330	Dacthal (DCPA)	0.20
					Cyanazine	1.00
			1/13/93	1330		*None Detected
			2/8/93	1730	Dacthal (DCPA)	0.15
					Cyanazine	0.40
					Diazinon	0.87
					Parathion	0.38
					Methidathion	8.80
		140.95	1/14/93	1200		*None Detected
31	Ford Group	143.06	2/21/86	1215		*None Detected
		143.12	3/24/92	930	Dacthal (DCPA)	0.38
33	Arroyo Pasajero	158.37	1/16/93	1300		*None Detected
		158.39	2/21/86	1050		*None Detected
34	Kettleman Hills Group	167.78	2/19/93	1035	Diazinon	0.06
	Other (City of Hesperia)	398.0	1/7/93	630		*None Detected

[1] *Shaded watersheds highlight major contributing inputs.*

* *No chemicals were detected in one or more scans.*

The two most commonly detected chemicals in floodwater inflows were the herbicides cyanazine and Dacthal (dimethyl tetrachloroterephthalate or DCPA). They were each detected ten times (Table 11). Dacthal concentrations ranged from 0.04 to 2.20 ug/l with a median of 0.20 ug/l. Cyanazine levels ranged from 0.3 to 13 ug/l with a median of 0.80 ug/l. Both were detected in floodwaters from the two major contributing watersheds on several occasions. Diuron (a similar herbicide) was detected four times with a median concentration of 0.80 ug/l and a range of 0.08 to 0.80 ug/l.

Both cyanazine and Dacthal are pre– and early post–emergence herbicides (WSSA, 1983). Applications may have been made in preparation for planting or for weed control in general. Pesticide residues would remain for some time after application according to their degradation rates (half–life=15–100 days). Therefore, off–site transport is possible when the applications are followed within a reasonable period by a runoff producing storm event.

Diazinon, methadathion, and ethyl parathion were detected in floodwater inflows four, two, and one time, respectively (Table 11). All three compounds were usually below 1ug/l. Diazinon concentrations ranged from 0.06 to 0.87 ug/l with a median of 0.61 ug/l. Methadathion was detected twice at 0.02 and 8.80 ug/l. Parathion was detected once at 0.38 ug/l.

Diazinon, methadathion, and parathion are applied to stone fruit trees (almond, apricot, peach) to prevent flower bud predation by insects. Although not as extensive as ground crops, orchards are common west of the SLC. These pesticides are usually applied between winter and early spring (January–April). Off–site transport can occur when rainfall events are preceded by applications.

Other chemicals detected in floodwater inflows included pentachlorophenol, tris–phosphate, and an unknown chemical (Table 11). Pentachlorophenol was detected at 0.40 ug/l and was below the federal primary MCL of 1 ug/l. Tris–phosphate was detected twice at 0.20 and 1.30 ug/l, and an unknown or several unknowns were detected at 2 ug/l based on an internal standard.

V. San Luis Canal Water Quality Assessment

Changes in SLC water quality from floodwater inflows were assessed in this chapter using data from monthly grab samples collected at Checks 13 and 21. Check 13 is at the outlet of O'Neill Forebay (milepost 70.89) and represents the upstream station unaffected by SLC floodwaters (Figure 1). Check 21 is at milepost 172.44 downstream of all SLC drain inlets. A mass loading assessment of certain constituents of concern follows the grab sample section.

Grab Sample Data

Upstream/downstream comparisons were performed for rainy season months (November through April) with high floodwater inflows - 1980, 1983, and 1986. During these years total floodwater inflows were, respectively, 8,223 af, 22,345 af, and 6,879 af. Hardness, TDS, sulfate, and boron concentrations were compared to Article 19 objectives. These water quality parameters were included because they were elevated in floodwaters from the major contributing watersheds. An assessment of organic chemicals and asbestos was also included. Sampling, analytical, and quality control information is in Appendix B. Water quality data for Checks 13 and 21 between 1979 to 1990 are in Appendix D.

Minerals

Total Dissolved Solids: During the 1980 rainy season, TDS concentrations at Checks 13 and 21 were similar to each other except for February (Figure 5). In February, the TDS concentration increased by 117 percent from 175 mg/l at Check 13 to 379 mg/l at Check 21. During the other rainy season months, TDS values at both stations ranged from 170 to 264 mg/l. The Article 19 objective monthly average of 440 mg/l was not exceeded in any of the rainy season samples for that year.

During the 1983 rainy season, the TDS concentration was higher at Check 21 compared to Check 13 for three consecutive months (Figure 5). The increase in TDS ranged from 43 to 191 percent. Values during February, March, and April were, respectively, 194 mg/l, 207 mg/l, and 162 mg/l at Check 13 and 437 mg/l, 296 mg/l, and 471 mg/l at Check 21. The TDS concentration at Check 21 exceeded the Article 19 objective in April and was close (437 mg/l) in February. During the other rainy season months, TDS at both stations ranged from 129 to 171 mg/l.

During the 1986 rainy season, TDS levels at Checks 13 and 21 were not substantially different from each other (Figure 5). Values at both stations ranged from 182 to 403 mg/l. The Article 19 objective for TDS was not exceeded in any of the rainy season samples for that year.

Hardness: During the 1980 rainy season, hardness concentrations at Checks 13 and 21 were similar to each other except for February (Figure 5). In February, the hardness concentration increased 133 percent from 66 mg/l at Check 13 to 154 mg/l at Check 21. The Article 19 objective monthly average of 180 mg/l was not exceeded in any of the rainy season samples for that year.

During the 1983 rainy season, the hardness concentration was higher at Check 21 compared to Check 13 for 3 consecutive months (Figure 5). The increase in hardness ranged from 54 to 200 percent. Values during February, March, and April were, respectively, 78 mg/l, 84 mg/l, and 69 mg/l at Check 13 and 187 mg/l, 129 mg/l, and 207 mg/l at Check 21. The hardness concentrations at Check 21 exceeded the Article 19 Objective during February and April. During the other rainy season months, hardness at both stations ranged from 50 to 66 mg/l.

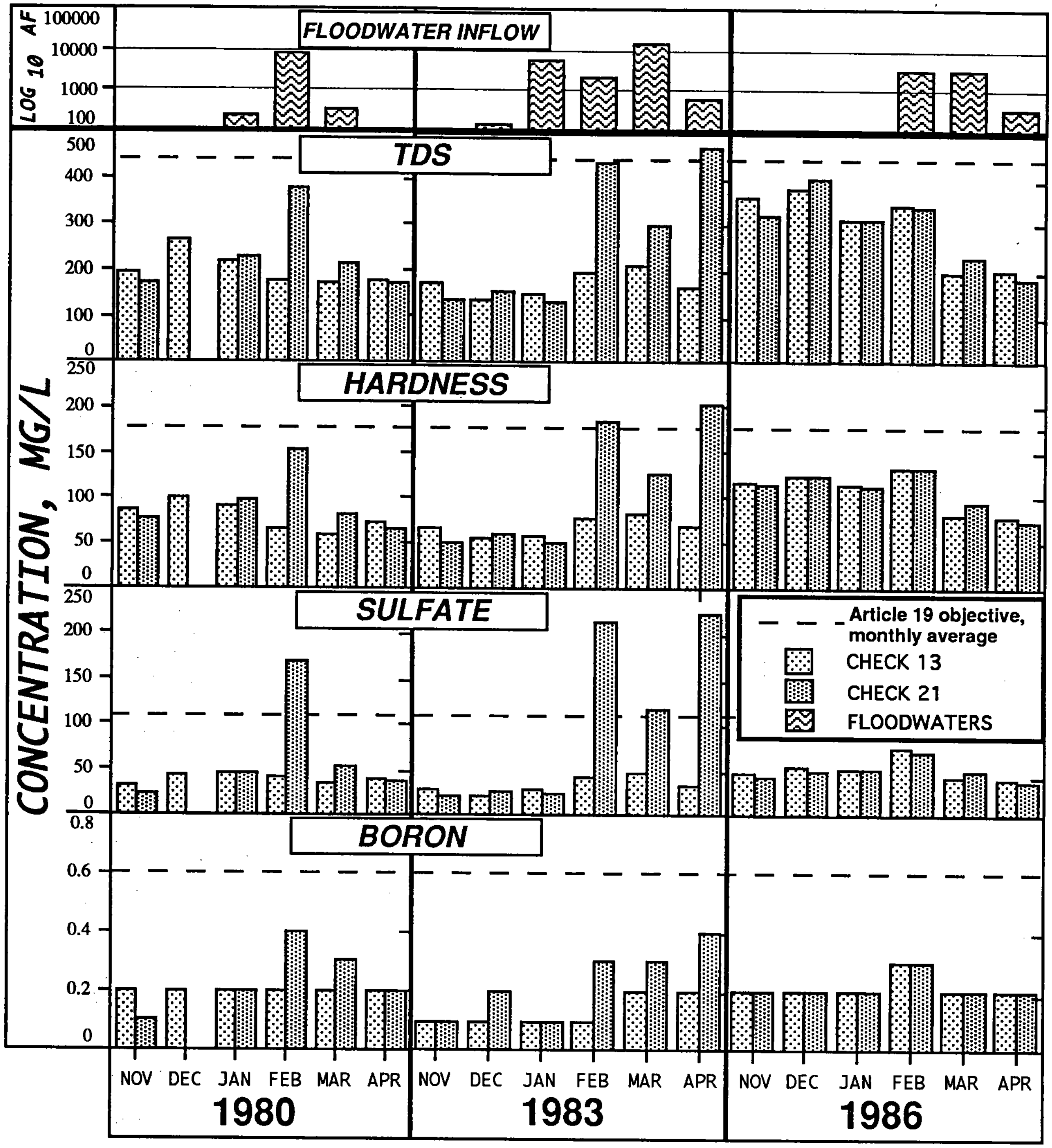

Figure 5. Total Dissolved Solids, Hardness (as $CaCO_3$), Sulfate, and Boron in the SLC at Checks 13 and 21.
Grab samples collected monthly during the rainy seasons (November through April) of 1980, 1983, and 1986. Parameters were chosen because they were above water quality thresholds in floodwaters from at least one of the major contributing watersheds. Top graph shows total monthly floodwater inflows in acre-feet for drain inlets in the study area.

During the 1986 rainy season, hardness levels at Checks 13 and 21 were not substantially different from each other (Figure 5). Values at both stations ranged from 74 to 134 mg/l. The Article 19 Objective was not exceeded in any of the rainy season samples for that year.

Sulfate: During the 1980 rainy season, sulfate concentrations at Checks 13 and 21 were similar to each other except for February (Figure 5). In February, the sulfate concentration increased by 167 percent from 40 mg/l at Check 13 to 167 mg/l at Check 21. The February value at Check 21 exceeded the Article 19 objective monthly average of 110 mg/l. During the other rainy season months, sulfate ranged from 23 to 51 mg/l.

During the 1983 rainy season, the sulfate concentration was higher at Check 21 compared to Check 13 for 3 consecutive months (Figure 5). The increase in sulfate ranged from 151 to 540 percent. Values during February, March, and April were, respectively, 44 mg/l, 47 mg/l, and 35 mg/l at Check 13 and 214 mg/l, 118 mg/l, and 224 mg/l at Check 21. Sulfate concentrations at Check 21 exceeded the Article 19 objective during February, March, and April. During the other rainy season months, sulfate at both stations ranged from 22 to 30 mg/l.

During the 1986 rainy season, sulfate levels at Checks 13 and 21 were not substantially different from each other (Figure 5). Values at both stations ranged from 36 to 73 mg/l. The Article 19 Objective was not exceeded in any of the rainy season samples for that year.

Boron: During the 1980 rainy season, boron concentrations at Checks 13 and 21 were similar to each other except for February (Figure 5). In February, the boron concentration increased by 100 percent from 0.20 mg/l at Check 13 to 0.40 mg/l at Check 21. During the other rainy season months, boron ranged from 0.1 to 0.3 mg/l. The Article 19 objective monthly average of 0.6 mg/l was not exceeded in any of the rainy season samples for that year.

During the 1983 rainy season, boron concentrations were higher at Check 21 compared to Check 13 for 3 consecutive months (Figure 5). The increase in boron ranged from 50 to 200 percent. Values during February, March and April at Check 13 were, respectively, 0.10, 0.20, and 0.20 mg/l and 0.30, 0.30, and 0.40 mg/l at Check 21. The Article 19 Objective was not exceeded in any of the rainy season samples for that year.

During the 1986 rainy season, boron levels at Checks 13 and 21 were exactly the same (Figure 5). The Article 19 objective was not exceeded in any of the rainy season samples for that year.

Asbestos

Asbestos levels in the SLC were compared between Checks 13 and 21 during the 1992 and 1993 rainy seasons (November–April). Total floodwater inflows were 2,884 and 5,539 af for 1992 and 1993, respectively. As mentioned in the previous chapter, analyses prior to 1991 were not included because they were reported as total number of fibers greater than five microns in length and were incomparable to the present method which measures asbestos fibers greater than 10 microns in length.

Although asbestos was rarely detected in the SLC, assessment of the effects of floodwater inflows was limited by high detection limits caused by elevated turbidity. All asbestos samples collected at Check 13 during the rainy seasons of 1992 and 1993 were below detection limits. Detection limits at Check 13 ranged from <1.1 to <14 MFL (Table 12). Sample waters high in suspended solids result in raised detection limits (Chatfield and Dillon, 1983). At Check 21, asbestos was detected in three of 12 samples. However, only one of the positive detections (19 MFL in December, 1993) coincided with floodwater inflows. This value was reported at the detection limit of <19 MFL and, therefore, may be related to normal variation in the analytical method. Detection limits at Check 21 ranged from <1.9 to <110 MFL. Although over half of the detection limits were above the primary MCL of 7 MFL, almost all asbestos is removed in the water treatment process (Condon, pers. comm.).

Table 12. Asbestos Concentrations in the SLC at Checks 13 and 21, Rainy Seasons 1992 and 1993.

(concentration, MFL [1])

Sample Date	Check 13	Check 21	Floodwater Inflows, af [5]
1992			
Nov. 18	<1.1	2.7 [2]	0
Dec. 18	<2	<2	0
Jan. 15	<1.1	<18	119
Feb. 19	<11	<11	2,025
Mar. 18	<11	<110	740
Apr. 15	<14	<14	0
1993			
Nov. 18	<1.9	<1.9	0
Dec. 16	<1.9	5.73 [3]	0
Jan. 20	<19	<19	0
Feb. 17	<19	<19	3,328
Mar. 17	<19	19 [4]	2,043
Apr. 21	<0.20	<4.2	168

[1] Million Fibers per Liter of fibers >10 microns in length.
[2] Detection limit = 1.3. MFL
[3] Detection limit = 1.9 MFL
[4] Detection limit = 19 MFL
[5] Total monthly SLC floodwater inflows in acre–feet.

Table 13. Organic Chemicals in the Aqueduct at Check 21, Banks Pumping Plant, and the Delta–Mendota Canal. [1]

Check 21 [2]			Banks Pumping Plant			Delta–Mendota Canal [3]		
Date	Compound	UG/L	Date	Compound	UG/L	Date	Compound	UG/L
2/18/87	Ethyl Parathion	0.018	2/18/87	Atrazine	0.040			
2/18/87	Diazinon	0.034	2/18/87	Diazinon	0.020			
2/18/87	Atrazine	0.110						
2/17/88	Simazine	0.200				2/17/88	Simazine	0.10
						2/17/88	Atrazine	0.30
						2/17/88	Bromoethane	17
						5/18/88	Simazine	0.123
2/16/89	Diazinon	0.130				2/15/89	Simazine	0.18
11/14/89	Unknown					11/15/89	None Detected	
2/20/91	Diuron	0.210	2/20/90	Diuron	0.110	2/21/90	Diuron	0.66
						2/21/90	Unknown Chlorinated organic	
11/14/90	Chloromethane	0.600	11/13/90	2,4,–D	0.100	11/14/90	2,4,–D	0.40
			11/13/90	Trichloro–ethylene	0.500			
2/20/91	Diuron	0.250	2/19/91	Diuron	0.200	2/20/91	Diuron	0.50
11/19/91	None Detected		11/19/91	None Detected		11/20/91	2,4,–D	0.10
2/19/92	Diuron	1.200	2/19/92	Diuron	0.700	2/19/92	Diuron	8.80
2/19/92	Dacthal (DCPA)	0.060				2/19/92	Diazinon	0.14
11/18/92	None Detected		11/18/92	None Detected		11/18/92	None Detected	
2/17/93	Diazinon	0.100	2/17/93	Diazinon	0.100	2/17/93	Diazinon	0.42
						2/17/93	Methidathion	0.06
11/17/93	2,4,–D	0.200	11/17/93	2,4,–D	0.200			

[1] Shaded data highlight chemical detections at Check 21 which were also found at two upstream sites around the same sampling date.
[2] Data with the striped shading indicate detections that may have been caused by drain inlets.
[3] Samples collected at O'Neill Forebay Pumping Plant from 1988 to July 1991 and from the Delta–Mendota Canal from August 1991 to February 1993.

Organic Chemicals

An upstream/downstream comparison of organic chemicals was performed using data from Check 21 and two upstream stations at Banks Pumping Plant and the Delta Mendota Canal. Similar data was not available for Check 13. Organic chemical analyses include one or more U.S.EPA methodology scans of major chemical classifications such as purgeable organics, chlorinated organic pesticides, organic phosphorus pesticides, chlorinated and phenoxy acid herbicides, carbamates, and miscellaneous pesticides such as glyphosate.

Most organic chemicals detected in the SLC were pesticides. Pesticides were detected in 11 of 15 water samples collected at Check 21 (Table 13). Chloromethane was detected in one sample, one contained an unknown compound, and no detectable chemicals were present in two of the samples.

Seven of the pesticide detections at Check 21 coincided with detections of the same compound in Delta waters upstream from the SLC. Diazinon, simazine, diuron, and 2,4,-D were detected at Check 21 on the same day (or one day after) these pesticides were reported in the aqueduct at Banks Pumping Plant (Table 13). Several pesticides detected at Check 21 were also present in the Delta Mendota Canal during the same sampling periods. Although floodwater inflows could have augmented SLC concentrations, pesticide residues were already present from Delta sources. Of the four pesticide detections at Check 21 that did not coincide with Delta water detections, two were associated with floodwater inflows. Diazinon and Dacthal were present at Check 21 during a period of floodwater inflow. These chemicals have also been detected in floodwater inflows. The other chemical detections at Check 21 were not related to either upstream detections on the same day or floodwater inflows.

Mass Loads

Mass load comparisons were made between SLC floodwater inflows, Banks Pumping Plant, and water pumped into O'Neill Forebay from the Delta Mendota Canal. Mass loads of sulfate, selenium, iron, TSS, and TDS were converted to percent-of-total values, i.e., floodwater loads as a percent of all loads coming in from the Delta. A more detailed description of the calculation methods is in Appendix B.

Figure 6 shows the relative monthly loading contributions from floodwater inflows. Monthly sulfate loading ranged from less than 1 percent to over 13 percent. Most of the sulfate percentages (15 of 20) were below 5 percent. Values for iron ranged from less than 1 percent to 2.5 percent. Total dissolved solids percentages ranged from less than 1 percent to more than 6 percent and over half were below 1 percent. Selenium loading percentages ranged from less than 1 percent to 12 percent and half were under 1 percent. Floodwater inflow loading contributions were highest for TSS, ranging from less than 1 percent to 78 percent. Half of the TSS loading values were below 5 percent and a majority of the other half were above 20 percent.

With the possible exception of TSS, mass loading contributions made by floodwater inflows were relatively small. This was expected for most parameters due to the infrequency of floodwater inflows and the relatively small volumes admitted to the aqueduct compared to what is pumped in from Delta sources. Conversely, the amount of TSS contributed by floodwaters was, at times, considerable.

Dredging sediment from the aqueduct has been performed in the past after heavy rainy seasons. After the 1978 rainy season, a total of 3,000-4,000 cubic yards of sediment was removed from four sand traps located between milepost 172 and 294 (Lucas 1979). An estimated 11,000 cubic yards deposited in front of Edmonston Pumping Plant also had to be dredged. Dredging was either contracted out or performed as part of the field division's routine maintenance duties. Although an increase in the Arroyo Pasajero holding capacity will result in lower TSS loads for rainy seasons similar to 1978, the holding capacity in the Salt and Cantua creek watersheds is limited. Peak TSS levels were detected in floodwaters from these watersheds. Other (possibly greater) sources of sediment to the aqueduct include Delta water deposits and windblown dust from surrounding agricultural fields.

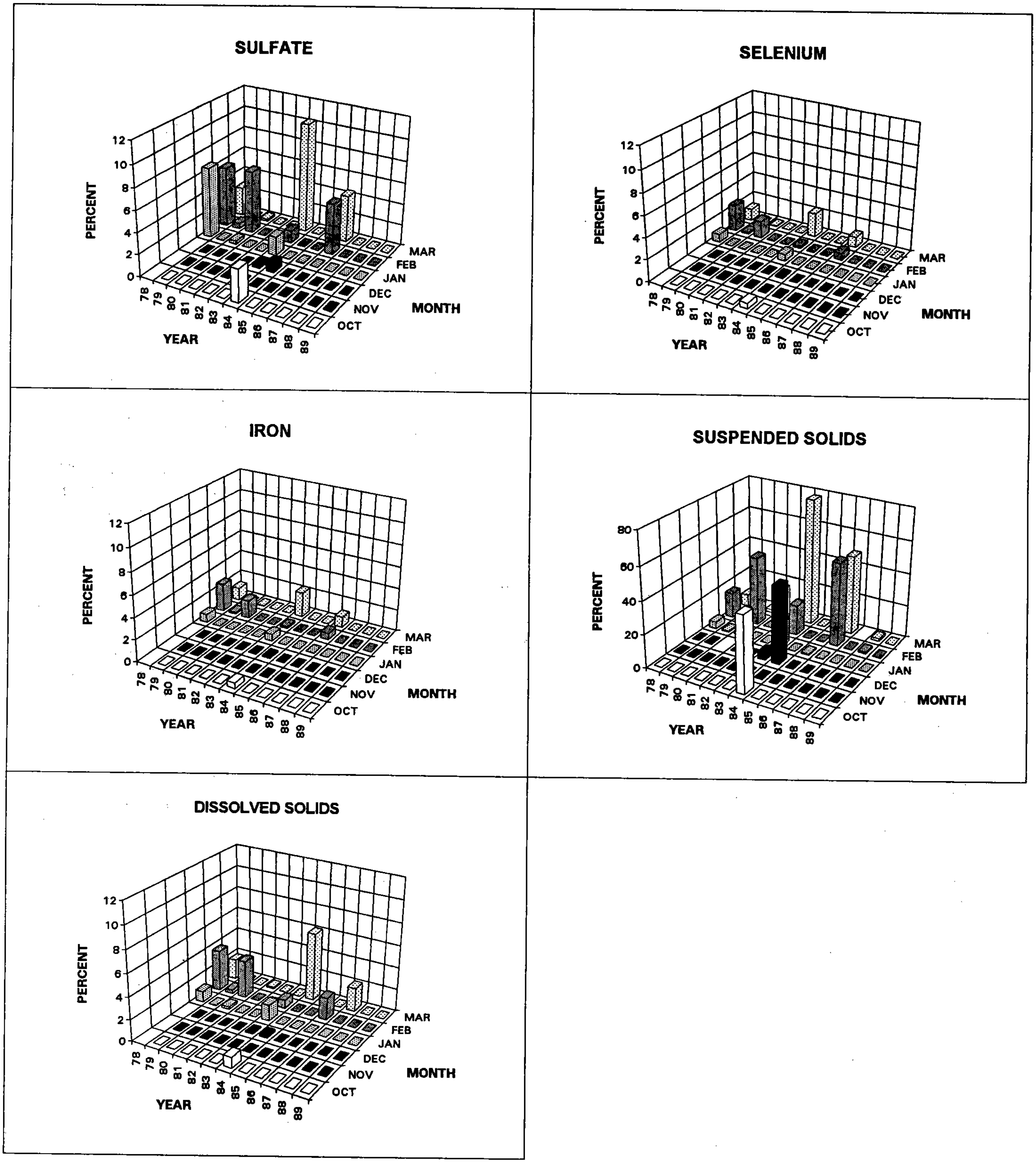

Figure 6. Relative Loading Inputs from SLC Floodwater Inflows.

Floodwater loading of sulfate, selenium, iron, and suspended and dissolved solids are presented as percent-of-total values. Floodwater loads as a percent of all monthly contributions from floodwater inflows, Banks Pumping Plant, and O'Neill Pumping Plant (Delta-Mendota Canal).

VI. Conclusions And Recommendations

Conclusions

Floodwater Quality

The water quality of floodwater inflows was evaluated using data from 1986 through 1993. Categories included minerals, minor elements, asbestos, nutrients, organic chemicals, and miscellaneous parameters. Data from individual drain inlets in the San Luis Field Division were combined and averaged by watershed. Floodwater data combined by watershed reflects concentrations similar in their geochemical make-up. Averages were compared to water quality thresholds to assess relative concentrations. Constituents that exceeded the WQTs were most likely to affect SLC water quality and were assessed further in the SLC upstream/downstream comparisons. Exceedences of the WQTs do not imply impacts. Table 14 summarizes floodwater quality in the San Luis Field Division. The major findings are:

1. Salinity, hardness, sulfate, and boron levels exceeded WQTs in a majority of the watersheds sampled. The salts are leaching from naturally occurring marine deposits in the Diablo Range. All were above WQTs in the major contributing watersheds.

Salinity: Electrical conductivity (or specific conductance) ranged from 41 to 8,150 uS/cm with a median of 1,098 uS/cm. It exceeded the recommended secondary Maximum Contaminant Level of 900 uS/cm in 57 percent of the watersheds sampled. Total dissolved solids ranged from 57 to 6,488 mg/l with a median of 713 mg/l. It exceeded the Article 19 objective monthly average of 440 mg/l in 64 percent of the watersheds sampled.

Hardness: Hardness ranged from 9 to 1,670 mg/l with a median of 289 mg/l. It exceeded the Article 19 objective monthly average of 180 mg/l in 79 percent of the watersheds sampled.

Sulfate: Sulfate ranged from 2 to 2,400 mg/l with a median of 283 mg/l. It exceeded the Article 19 objective monthly average of 110 mg/l in 64 percent of the watersheds sampled.

Boron: Boron ranged from <0.1 to 4.0 mg/l with a median of 0.07 mg/l. It exceeded the Article 19 objective monthly average of 0.6 mg/l in 57 percent of the watersheds sampled.

2. Minor elements were not universally elevated in floodwater inflows; however, aluminum, iron, manganese, and selenium infrequently exceeded the WQTs. None of the exceedences occurred in the major contributing watersheds.

Aluminum: Aluminum ranged from 1 to 1,418 ug/l with a median of 23 ug/l. It exceeded the Primary MCL of 1,000 ug/l in one of the 12 watersheds sampled. The high value was inconsistent for Diablo Range floodwaters, indicating a nonnatural source or sources.

Table 14. Summary of Floodwater Quality in the San Luis Field Division. [1]

Water Quality Parameters Analyzed	Units	Concentration [5] Med.	Min.	Max.	Watersheds # of Samples Collected	# Sampled [2]	# That Exceed WQTs (%) [3]	WQT [4]
Minerals								
Alkalinity (as $CaCO_3$)	mg/l	95	16	221	41	14	N.A.	
Hardness (as $CaCO_3$)	mg/l	289	9	1,670	40	14	11 (79) **	A19MO
pH	pH	7.6	6.6	8.2	41	14	N.A.	
Specific Conductance	uS/cm	1,098	41	8,150	41	14	8 (57) **	MCL2S
Total Dissolved Solids	mg/l	713	57	6,488	41	14	9 (64) **	A19MO
Boron	mg/l	0.07	<0.1	4	40	14	8 (57) *	A19MO
Calcium	mg/l	77	2	567	40	14	N.A.	
Chloride	mg/l	52	1	1,194	40	14	3 (21)	A19MO
Fluoride	mg/l	0.2	<0.1	0.4	40	14	0	A19MX
Magnesium	mg/l	24	1	224	40	14	1 (7)	A19MX
Potassium	mg/l	12	4	18	4	2	N.A.	
Sodium	mg/l	93	1	1,078	40	14	N.A.	
Sulfate	mg/l	283	2	2,400	40	14	9 (64) **	A19MO
Minor Elements								
Aluminum	ug/l	23	1	1,418	29	12	1 (8)	MCL1S
Arsenic	ug/l	2	1	14	43	14	0	A19MX
Barium	ug/l	126	<5	171	30	13	0	MCL1S
Cadmium	ug/l	<5	<5	<5	33	13	0	MCL1S
Chromium (total)	ug/l	<5	<5	6	43	14	0	MCL1S
Copper	ug/l	6	<5	22	43	14	0	A19MX
Iron	ug/l	31	5	849	47	14	2 (14)	A19MX
Lead	ug/l	<5	<5	<5	43	14	0	A19MX
Manganese	ug/l	18	<5	790	43	14	1 (7)	A19MX
Mercury	ug/l	<1	<1	<1	42	14	0	MCL1S
Selenium	ug/l	6	<1	182	46	14	2 (14)	A19MX
Silver	ug/l	<5	<5	<5	29	11	0	MCL1S
Zinc	ug/l	6	5	29	45	14	0	A19MX
Asbestos	MFL [6]	<210	<5.3	1,900	9	3	N.A.	
Nutrients								
Dissolved Ammonia	mg/l	0.12	0.02	0.41	5	5	N.A.	
Dissolved Phosphorous	mg/l	0.11	0.04	0.41	5	5	N.A.	
Nitrate (as NO_3)	mg/l	6	<0.1	51	39	13	2 (15)	MCL1S
Nitrate + Nitrite (as N)	mg/l	1.2	0.3	2.1	5	5	0	MCL1F
Organic Nitrogen	mg/l	1.4	0.7	4.2	5	5	N.A.	
Total Phosphorous	mg/l	1.3	0.06	2.5	5	5	N.A.	
Miscellaneous								
Bromide	mg/l	0.16	0.01	0.77	15	7	N.A.	
Total Organic Carbon	mg/l	9.1	1	40.9	30	9	N.A.	
Total Suspended Solids	mg/l	265	22	5,150	33	10	N.A.	

[1] Study area includes the SLC and a 21-mile reach of aqueduct north of the SLC within the San Luis Field Division. Water quality data collected from 1986 to 1993.
[2] Number of watersheds (out of 34) from which floodwater inflows were sampled.
[3] Number of watersheds where floodwaters exceeded the water quality threshold. The number in parentheses is the percent of the watersheds sampled that exceeded WQTs.
*** = above WQT in two major contributing watersheds.*
** = above WQT in one major contributing watershed.*
[4] WQT = water quality threshold
A19MO = Article 19 Objective, monthly average.
A19MX = Article 19 Objective, maximum.
MCL1S = maximum contaminant level, primary drinking water standard, State.
MCL2S = maximum contaminant level, secondary drinking water standard, State.
MCL1F = maximum contaminant level, primary drinking water standard, federal.
[5] Median, minimum, maximum.
[6] MCL = Million Fibers per Liter.

Iron: Iron ranged from 5 to 849 ug/l with a median of 31 ug/l. It exceeded the Article 19 objective maximum of 300 ug/l in two of the 14 watersheds sampled. The high values were inconsistent for Diablo Range floodwaters, indicating a non-natural source or sources.

Manganese: Manganese ranged from <5 to 790 ug/l with a median of 18 ug/l. It exceeded the Article 19 objective maximum of 300 ug/l in one of the 14 watersheds sampled.

Selenium: Selenium ranged from <1 to 182 ug/l with a median of 6 ug/l. It exceeded the Article 19 objective maximum of 50 ug/l in two of the 14 watersheds sampled. However, floodwaters from one of those watersheds (Billie Wright Creek) is not admitted into the SLC. Selenium is originating from certain geological formations that dominate the surface geology of a few watersheds.

3. Nutrients were not universally elevated in floodwater inflows, however, nitrate exceeded the WQT in two watersheds. None of the exceedences occurred in the major contributing watersheds.

Nitrate: Nitrate (as NO_3) ranged from <0.1 to 51 mg/l with a median of 6 mg/l. It exceeded the primary MCL of 45 mg/l in two of the 13 watersheds sampled. However, floodwaters from one of the watersheds (Billie Wright Creek) is not admitted into the SLC.

4. Total organic carbon and total suspended solids were elevated in floodwater inflows.

TOC: Total organic carbon ranged from 1.0 to 40.9 mg/l with a median of 9.1 mg/l. Trihalomethane formation potential may be correspondingly elevated.

TSS: Total suspended solids ranged from 22 to 5,150 mg/l with a median of 265 mg/l. High levels are from erosional materials carried across the alluvial fans in high velocity floodflows.

5. Herbicides and pesticides were detected in about half the floodwater samples analyzed. More than half of the detections were from the major contributing watersheds (Table 15).

Cyanazine and Dacthal (dimethyl tetrachloroterephthalate or DCPA) were the most frequently detected pesticides in the major contributing watersheds. Diuron, diazinon, methadathion, and parathion were also detected in floodwater inflows.

6. Asbestos was infrequently detected in floodwater inflows from Salt and Cantua creeks although assessment was hindered by high detection limits caused by elevated turbidity.

SLC Water Quality

Water quality in the SLC was assessed using monthly grab sample data from Checks 13 and 21. Check 13 represents the upstream station unaffected by SLC floodwaters and Check 21 is located downstream all SLC drain inlets. Upstream/downstream comparisons were performed for TDS, hardness, sulfate, and boron. These four parameters were included because they were elevated in floodwaters from the major contributing watersheds (Salt and Cantua creeks), and thus, most likely to change SLC water quality. Comparisons were made for the rainy season months October–April during years of high floodwater inflows – 1980, 1983, and 1986. For asbestos, upstream/downstream comparisons were performed for the rainy season months of 1992 and 1993. Asbestos levels reported prior to 1991 were incomparable to more recent data and the MCL. Pesticides and TSS were also included in the assessment. The major findings are:

Table 15. Summary of Organic Chemicals Detected in Floodwater Inflows and the SLC at Check 21.

Organic Chemical	Floodwaters: # of Detections[1] Study Area	Floodwaters: # of Detections[1] Major Drains	Floodwaters: Concentrations, UG/L[3] Med.	Min.	Max.	Aqueduct at Check 21[2]: # of Detections	Aqueduct: Concentrations, UG/L[3] Med.	Min.	Max.
2,4,–D	—					1	0.20		
Atrazine	—					1	0.11		
Chloromethane	—					1	0.60		
Cyanazine	10	8	0.80	0.30	13.00	—			
Dacthal (DCPA)	10	6	0.20	0.04	2.20	1	0.06*		
Diazinon	4	1	0.61	0.06	0.87	3	0.10	0.034	0.13*
Diuron	4	4	0.80	0.08	0.80	3	0.25	0.21	1.20
Ethyl Parathion	—					1	0.018		
Methidathion	2	1	—	0.02	8.80	—			
Parathion	1	1	0.38			—			
Pentachlorophenol (PCP)	1	1	0.40			—			
Simazine	—					1	0.11		
Tris Phosphate	2	1	—	0.20	1.30	—			
Unknown(s)	1	0	2.0			—			
None Detected	15	4				2			

[1] *Number of times detected in:*
Study Area: Includes floodwater samples from drain inlets in the SLC and a 21-mile reach of aqueduct north of the SLC (Milepost 45.97–172.44).
Major Drains: Includes floodwater samples from the major contributing drains (Salt and Cantua creeks).

[2] *Asterisk (*) indicates detections potentially caused by floodwater inflows.*

[3] *Concentration: median, minimum, maximum.*

1. Total dissolved solids, hardness, sulfate, and boron levels increased between Checks 13 and 21 in several rainy season months during 1980 and 1983 but not 1986 (Figure 7).

TDS: In February 1980, TDS at Check 21 was 117 percent higher than at Check 13. During 1983, TDS was 43 to 191 percent higher at Check 21 for three consecutive months and exceeded the Article 19 objective monthly average in April. No substantial increases were measured in the 1986 samples.

Hardness: In February 1980, hardness at Check 21 was 133 percent higher than at Check 13. During 1983, hardness was 54 to 200 percent higher at Check 21 for three consecutive months and exceeded the Article 19 objective monthly average in February and April. No substantial increases were measured in the 1986 samples.

Sulfate: In February 1980, sulfate at Check 21 was 318 percent higher than at Check 13 and exceeded the Article 19 objective monthly average. During 1983, sulfate was 151 to 540 percent higher at Check 21 for three consecutive months and exceeded the Article 19 objective monthly average in all three months. No substantial increases were measured in the 1986 samples.

Boron: In February 1980, boron at Check 21 was 100 percent higher than at Check 13. During 1983, boron was 50 to 200 percent higher at Check 21 for four months. No increases were measured in the 1986 samples.

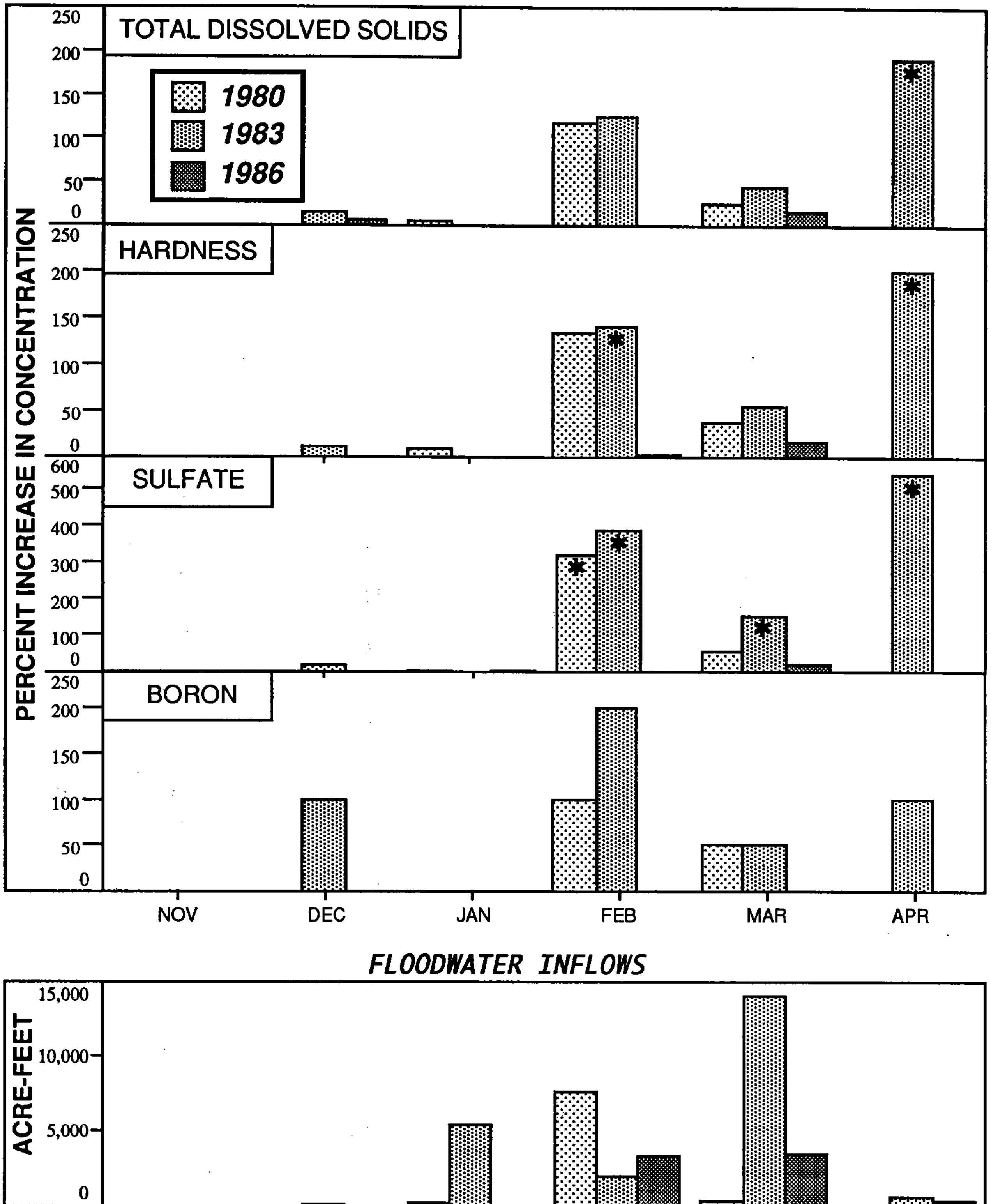

Figure 7. Increase in Concentration of TDS, Hardness, Sulfate, and Boron in the SLC at Checks 13 and 21.

Reported as percent increase in concentration during the rainy season months of 1980, 1983, and 1986. Monthly floodwater inflows for each month are reported in the bottom graph. An asterisk (*) indicates months in which concentrations exceeded the Article 19 objective monthly average at Check 21.

2. Floodwater inflows, at times, contributed a considerable amount of sediment to the aqueduct. During months of inflow, floodwaters contributed 1 to 78 percent of the combined monthly TSS loads from Delta pumping and floodwaters. Almost half of the monthly loads were above 20 percent and the other half were below five percent.

3. Floodwater inflows rarely influenced pesticide levels in the SLC (Table 15). Diazinon and Dacthal were detected once each at Check 21 during a period of floodwater inflow.

4. Floodwater inflows did not affect SLC asbestos concentrations during 1992 or 1993, although, assessment was hindered by high detection limits caused by elevated turbidity.

Recommendations

Guidelines for monitoring floodwater inflows are stipulated in Project Operations and Maintenance Instruction Number OP–13 (see Appendix E). The guidelines instruct field divisions to collect water quality samples whenever possible. Actual sampling decisions have been determined largely by drain size and the practicality of getting to a site during a runoff inducing event. Table 16 shows that floodwaters from Salt Creek, Cantua Creek, and the Jorden Group have been more extensively sampled than the other watersheds. Although samples collected in this manner have generally produced a good database, information gaps remain.

Seven monitoring strategies as well as continued cyclic monitoring at the major contributing watersheds are recommended to fill information gaps identified in the present database. These strategies were designed to be limited and cost–effective with the intention that any unusual results would flag areas that may require followup. The recommended monitoring strategies listed below are in no particular order.

1. Drain inlets from the major contributing watersheds (Salt, Cantua, and possibly Little Panoche creeks) should remain the primary cyclic monitoring locations.

This will improve the database since most inflows come from these watersheds. Cyclic monitoring can serve as a sentinel to watershed activities that may prove detrimental to water quality (e.g., construction, pesticide applications, etc.). Cyclic monitoring is identified with a "C" in Table 16. Cyclic monitoring for nutrients is also recommended in watersheds 19, 20, and 31.

2. Analyze minerals in floodwater inflows from watersheds with no existing data.

Inflows from the smaller watersheds may be important if they are unusually mineralized. Highly mineralized waters originate from watersheds dominated by marine deposits. Sampling unmonitored floodwaters could also reveal any undesirable influences from altered land–use features (e.g., developments, grazing, farm practices, etc). This monitoring is identified in Table 16 as "SS(Mnrls)" for Special Study with a focus on minerals.

3. Analyze selenium in floodwater inflows from the Monocline Ridge area.

Floodwaters from watershed I.D. Nos. 24–27 may contain high levels because the surface geology is dominated by selenium–laden soils. One sample from watershed I.D. No. 26 has confirmed the elevated presence of selenium.

4. Analyze minerals in ground water from sump pumps.

Several ground water springs emanating from the Diablo Range have the characteristics of dilute sea water. They contain elevated levels of salts and sometimes other naturally occurring elements such as selenium. No data exists to determine if these water types are influencing groundwaters pumped into the aqueduct at sump pumps. There are eight sump pumps in the Volta Group (watershed I.D. No. 13) that pump ground water to relieve hydrostatic pressure on the aqueduct liner.

5. Inspect the Kettleman Hills Group watershed to determine if there are any unusual pollutant sources.

Floodwater inflows from the Kettleman Hills Group (watershed I.D. No. 34) contained peak levels of aluminum, iron, total organic carbon, and total suspended solids. The high concentrations were dissimilar to the characteristics of other Diablo Range floodwaters and may be originating from a nonnatural source or sources.

6. Analyze settleable solids in floodwater inflows from the major contributing watersheds.

Floodwater inflows may be a significant source of sediments to the aqueduct. Sampling the major contributing watersheds for settleable solids would provide data to estimate sediment loads. A comparison with the amount of sediment dredged from the aqueduct would indicate the relative contribution compared to other sources (i.e., wind blown dust, Delta inputs).

7. Include TSS and TOC analyses in routine grab sampling at Checks 13 and 21 during the months of January, February, and March.

Upstream/downstream comparisons can be made to further quantify the effects of floodwater inflows on SLC water quality.

Table 16. Historical Floodwater Monitoring Frequency and Recommended Sampling Strategies.

Watershed			Number of Samples Collected, 1986–1993					Recommended Monitoring [3]				
I.D. # [1]	Milepost Range	Name	Minerals	Minor Elements	Nutrients	Miscellaneous [2]	Organics	Minerals	Minor Elements	Nutrients	Miscellaneous [2]	Organics
1	45.97 – 47.10	Crow Creek										
2	47.10 – 50.63	Crow Creek Hills Group	1	1								
3	50.63 – 52.03	Oristimba Creek										
4	52.03 – 56.20	Bennett Valley Group										
5	56.20 – 57.67	Garzas Creek										
6	57.67 – 61.73	Mustang Creek										
7	61.73 – 65.00	Quinto Creek				1						
8	65.00 – 66.10	Romero Creek										
9	66.10 – 66.85	ONeill Forebay drng, N.	1	1			1					
10	66.85 – 70.60	O'Neill Forebay										
San Luis Canal								**San Luis Canal**				
11	70.60 – 74.10	O'Neill Forebay drng, S.						SS (Mnrls)				
12	74.10 – 74.80	Billie Wright drainage	2–3	1	1		1	No inflows from this watershed				
13	74.80 – 78.36	Volta Group						SS [4] (Mnrls)				
14	78.36 – 79.50	Los Banos Creek						No inflows from this watershed				
15	79.50 – 82.00	Salt Creek Group (Merced Co.)						SS (Mnrls)				
16	82.00 – 84.40	Ortigalita Creek Group	1	1		1–2	2					
17	84.40 – 87.78	Dos Amigos						SS (Mnrls)				
18	87.78 – 89.55	Laguna Seca Creek	1	1					SS (Mn)			
19	89.55 – 93.70	Etcheverry Group						SS (Mnrls)		C (N Cmds)		
20	93.70 – 95.40	Wildcat Canyon						SS (Mnrls)		C (N Cmds)		
21	95.40 – 96.78	Little Panoche Creek	1	1		1	1	C	C	C	C, SS (Setsl)	C, SS (TTHMFP)
22	96.78 – 108.50	Panoche Hills Group						SS (Mnrls)				
23	108.50 – 110.85	Panoche Creek						No inflows from this watershed				
24	110.85 – 113.82	Tumey Hills Group						SS (salts)	SS (Se)			
25	113.82 – 119.50	Monocline Ridge Group	2	2		1–3	3		SS (Se)			
26	119.50 – 127.90	Arroyo Ciervo Group		1				SS (Mnrls)	SS (Se)			
27	127.90 – 131.55	Arroyo Hondo Group						SS (Mnrls)	SS (Se)			
28	131.55 – 134.88	Cantua Creek Group	7	6–13	1	1–6	6	C	C	C	C, SS (Setsl)	C, SS (TTHMFP)
29	134.88 – 138.24	Salt Creek Group (Fresno Co.)	10	4–13	2	4–8	8	C	C	C	C, SS (Setsl)	C, SS (TTHMFP)
30	138.24 – 141.90	Jordan Group	6	5–6	1	1	2					
31	141.90 – 144.70	Ford Group	1	1–2		5–8	3			C (N Cmds)		
32	144.70 – 154.11	Skunk Hollow	1	1								
33	154.11 – 163.95	Arroyo Pasajero	2	2–4		2–3	2					
34	163.95 – 172.58	Kettleman Hills Group	4	3		1	1		SS (All) [5]			

C = Cyclic (parameter of concern): sample whenever possible on a cyclic basis

SS = Special Study (parameter of concern): conduct one–time monitoring to determine if the parameter of concern is elevated.

[1] *Shaded numbers highlight the major contributing watersheds.*
[2] *Miscellaneous parameters = organic carbon, total suspended solids, and bromide*
[3] *Se = Selenium; Nn = Manganese, Setsl = Settleable Solids; N Cmds = Nitrogen compounds; Fe = iron; Al = aluminum; TTHMFP; Total Trihalomethane Formation Potential.*
[4] *Water sampling also in all of the sump pumps.*
[5] *Sampling for minor elements in all drain inlets or site inspection of the watersheds.*

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