DRAFT TECHNICAL MEMORANDUM NO. 4
SUMMARY OF PESTICIDE MONITORING
IN THE SACRAMENTO-SAN JOAQUIN DELTA WATERSHEDS
CALIFORNIA URBAN WATER AGENCIES
STUDY OF DRINKING WATER QUALITY IN DELTA TRIBUTARIES

June 28, 1994

Pesticides were not included in the list of constituents of concern to be evaluated in the Study of Drinking Water Quality in Delta Tributaries because previous reviews of pesticide data indicated that most pesticides were not detected in the Sacramento and San Joaquin rivers and Delta waterways; and when pesticides were detected they were found at concentrations well below drinking water standards. The Project Advisory Committee (PAC) determined that pesticide monitoring programs should be evaluated and the importance of pesticides as drinking water contaminants should be reassessed. The purpose of this technical memorandum is to summarize the information and results of pesticide monitoring programs conducted by various agencies in the Delta watersheds and to relate that information to this study. The relationship to this study involves the impact of pesticides on drinking water quality, the advisability of including pesticides in the loads calculations for this study, and assessing the need for additional pesticide monitoring with respect to drinking water quality effects.

The discussion of recent pesticide monitoring is prefaced with a summary of pesticide issues as discussed in the State Water Project (SWP) Sanitary Survey Report (Brown and Caldwell, 1990). The information on pesticide monitoring programs is then organized as follows:

1. Delta monitoring programs.
2. Delta tributary monitoring programs.

The final section of the memorandum contains conclusions and recommendations with regard to this study.

SUMMARY OF PESTICIDE ISSUES AS DISCUSSED IN THE 1990 SWP SANITARY SURVEY REPORT

Pesticides were discussed in the SWP Sanitary Survey (Brown and Caldwell, 1990) relative to one type of contaminant source, namely agricultural drainage. Agricultural drainage was discussed in that report for three geographic areas: the Sacramento River watershed, the San Joaquin River watershed, and the Delta. Agricultural drainage was discussed in terms of nutrients, metals, and other constituents as well as pesticides. Monitoring information included in that report generally consisted of data through 1988-1989. The pesticides monitoring information summarized in that report is discussed in more detail later in this memorandum.

The pesticides discussed in the Sacramento River watershed were primarily the two rice herbicides molinate (Ordram) and thiobencarb (Bolero). These pesticides are carried from the rice fields through the river system primarily in May and June of each year. The SWP Sanitary Survey examined the decline in the concentrations of these pesticides in the Sacramento River since the early 1980s. This decline was a result of agricultural management practices, introduced by the Department of Pesticide Regulation (DPR). These management practices primarily consist of holding the treated water for longer periods before discharge. Longer holding times allow these pesticides to degrade and dissipate. Some toxicity testing in rice field drains conducted by the Central Valley Regional Water Quality Control Board (Regional Board) had identified the presence of other pesticides as a concern to aquatic life.

Since 1990, several developments concerning rice field pesticides have occurred. The Regional Board has instituted performance goals for five pesticides in agricultural drainage. The concentrations of molinate and thiobencarb have ceased their rapid decline and appear to have stabilized at ranges above their respective performance goals. Additional studies have been conducted on the toxicity and pesticide concentrations of rice field drainage. Additional management practices have been studied and adopted. A more detailed discussion of these developments is provided in the section on Delta Tributary Monitoring Programs.

Two separate areas of the San Joaquin River watershed were discussed in the SWP Sanitary Survey: the subsurface agricultural drainage area on the west side of the watershed and the surface water agricultural drainage area on the east side. The primary concern with agricultural drainage on the west side of the San Joaquin River is salts and trace elements. Limited pesticide monitoring had been conducted on that drainage. On the east side, some toxicity testing conducted by the Regional Board had identified the presence of toxicity in the San Joaquin River attributed primarily to the surface agricultural drainage.

Since 1990, there has been additional work on pesticides in the subsurface drainage conducted as part of the San Joaquin River Study. There has been considerable work conducted on the toxicity and pesticide chemistry of the surface agricultural drainage in various studies. This work has recently expanded in geographic area and is now also being conducted in the Sacramento River watershed and in the Delta. This work is discussed in the section on Delta Tributary Monitoring Programs.

Delta islands agricultural drainage was discussed in the SWP Sanitary Survey Report principally with respect to trihalomethane formation potential (THMFP) and soils high in carbon content. The Interagency Delta Health Aspects Monitoring Program (IDHAMP) and the 1988 Delta Islands Drainage Investigation (DIDI) monitoring, conducted by the Department of Water Resources (DWR), had found a few pesticides at levels below drinking water standards. This work is discussed in the section on Delta Monitoring Programs.

In 1990, DWR combined the IDHAMP and DIDI into one monitoring program, the Municipal Water Quality Investigation (MWQI) Program. The primary focus of MWQI has been THMFP and the mineral quality of Delta waters. No further pesticide monitoring has been conducted under MWQI.

PESTICIDE STUDIES AND MONITORING PROGRAMS

Since the SWP Sanitary Survey Report was prepared, a number of studies and pesticide monitoring programs have been conducted. The recent studies and the studies discussed in the SWP Sanitary Survey Report are described in this section. Table 1 is a summary of monitoring programs which have either focused on or included pesticide monitoring. This table shows the pesticide issue being studied, the agencies involved, the water bodies monitored, and the pesticides detected. Pesticides with drinking water standards are italicized. Table 2 shows drinking water standards for those pesticides, which have been detected in the Delta and Delta tributaries.

Delta Monitoring Programs

Two studies conducted specifically with regard to the drinking water quality of the Delta have been conducted by DWR which included pesticide monitoring. These studies are the IDHAMP and the DIDI study. The monitoring programs conducted by DWR pursuant to D-1485 and the California Department of Boating and Waterways (DBW) are also discussed.

IDHAMP. DWR conducted this monitoring study primarily to characterize THMFP and general mineral water quality. The characterization of pesticide occurrence in Delta agricultural drains, the Delta channel system, and the headworks of the Delta export facilities was a relatively minor portion of the overall study.

The monitoring plan for pesticides was based on an evaluation of pesticide use in different counties; time of application; chemical water solubility, half-life, and partition coefficients; and the difficulty in treating with conventional water treatment processes. This evaluation was the basis for determining what pesticides would be most likely found in particular months and regions. The study was conducted from 1983 to 1987 during spring herbicide applications, summer pesticide applications, and the first winter storm runoff. Monitoring was conducted on three agricultural drains, eight river/slough locations, and the five major export facilities intakes.

Table 1. Summary of Pesticide Monitoring Data in the Delta and Delta Tributary Watersheds

Pesticide issue/project	Agencies	Monitoring period	Major rivers monitored	Pesticides detected	Minor creeks, minor sloughs, drains monitored	Pesticides detected
IDHAMP	DWR	1983-1987	Delta	*2,4-D*, 4,4-DDD, 4,4-DDE, *bentazon*, BHC-alpha, BHC-beta, BHC-gamma, *carbofuran*, *diazinon*, *dieldrin*, *dimethoate*, endosulfan, guthion, *methyl parathion*, *molinate*, paraquat, *parathion*, *simazine*, *thiobencarb*	Delta drains	*2,4-D*, *atrazine*, *bentazon*, BHC-gamma, dacthal, *glyphosate*, *molinate*, *thiobencarb*
DIDI	DWR	1988	--	--	Delta drains	*atrazine*, *bentazon*, *carbaryl*, methamidophos, *molinate*, *simazine*
D-1485	DWR	1975-present	Delta	diuron	--	--
Water Hyacinth Control Program	DBW	1980-present	Delta; San Joaquin, Merced, and Tuolumne rivers	*2,4-D*	Salt Slough	*2,4-D*
National Stream Quality Accounting Network	USGS	1985, 1988	San Joaquin River at Vernalis	cyanazine, DDE, DDT, *diazinon*, *dieldrin*, *ethion*, *lindane*, metachlor, *methyl parathion*, *parathion*	--	--
San Joaquin River Bioassay Study	RWQCB	1988-1990	San Joaquin River	*carbaryl*, *carbofuran*, *diazinon*, *dimethoate*, *methyl parathion*	--	--
San Francisco Estuary Toxic Contaminants Program	USGS	1990-present	Sacramento River, San Joaquin River	*carbaryl*, *carbofuran*, chlorpyrifos, *diazinon*, methidathian, *molinate*, *simazine*, *thiobencarb*	--	--
San Joaquin River Study	DPR	1991-1993	San Joaquin River	*aldicarb*, azinphos-methyl, *carbaryl*, *carbofuran*, chlorpyrifos, *diazinon*, *dimethoate*, ethyl parathion, fonofos, *malathion*, methidathion, methiocarb, methomyl, *oxamyl*, *parathion*, phosmet	Various drains and creeks	*aldicarb*, azinphos-methyl, *carbaryl*, *carbofuran*, chlorpyrifos, *diazinon*, *dimethoate*, ethyl parathion, fonofos, *malathion*, methidathion, methiocarb, methomyl, *oxamyl*, *parathion*, phosmet

Table 1. Summary of Pesticide Monitoring Data in the Delta and Delta Tributary Watersheds (continued)

Pesticide issue/project	Agencies	Monitoring period	Major rivers monitored	Pesticides detected	Minor creeks, minor sloughs, drains monitored	Pesticides detected
Winter Wheat Study	DPR	1992	Feather River, Sacramento River	*2,4-D*, dicambra, MCPA	Colusa Basin Drain, Sutter Bypass	*2,4-D*, dicambra, MCPA
Orchard and Alfalfa Study	RWQCB	1992	Sacramento, Feather, Mokelumne, San Joaquin, and Old rivers	bromacil, *diazinon*, diuron, flumeturon, methidathion, propham	Seven small Delta water-courses and six Delta sloughs	*carbofuran*, chlorpyrifos, *diazinon*, diuron
National Water Quality Assessment Program	USGS	1992-1994	San Joaquin River	chlorpyrifos, *diazinon*, methachlor, methidathion, *simazine*, triazine	--	--
Pesticide Tracer Study	USGS	1993	Sacramento and San Joaquin rivers, Carquinez Straights	*carbaryl*, chlorpyrifos, *diazinon*, methidathion	--	--
Rice Pesticide Control Program	DFG RWQCB DPR	1980-present	Sacramento River	*carbofuran, molinate, thiobencarb*	Major rice drains	bensulfuron methyl, *carbaryl*, *carbofuran*, chlorpyrifos, *malathion*, *methyl parathion*, *molinate*, propanil, *thiobencarb*
Rice Pesticides Transport Study	USGS	1990	Sacramento River	*carbofuran, molinate, thiobencarb*	--	--
Urban Runoff Toxicity Identification Evaluation Study	RWQCB	1993-1994	--	--	Sacramento and Stockton urban creeks and drains	*diazinon*

Key:

IDHAMP	Interagency Delta Health Aspects Monitoring Program
DWR	Department of Water Resources
DIDI	Delta Islands Drainage Investigation
DBW	Department of Boating and Waterways
USGS	United States Geological Survey
DFG	Department of Fish and Game
RWQCB	Regional Water Quality Control Board, Central Valley Region
DPR	Department of Pesticide Regulation

Note: Pesticides with drinking water standards are *italicized.*

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Table 2. Drinking Water Standards for Pesticides Detected in the Delta and Delta Tributaries

Pesticides, µg/l	Standard[a]	Highest concentration detected in major rivers[b]	Highest concentration detected in minor creeks, sloughs, drains[b]
2,4-D	70[f]/100[c]	~10	~10
Atrazine	3[c]	--	0.91
Bentazon	18[c]	~2.8	~2.8
Carbaryl	60[e]	3.95	8.4
Carbofuran	18[c]	1.33	4.4
Diazinon	14[e]	1.53	36.8
Dieldrin	0.05[e]	0.005	--
Dimethoate	140[e]	2.44	2.23
Ethion	35[e]	0.01	--
Glyphosate	700[c]	00	10.0
Lindane	0.2[f]	0.002	--
Malathion	160[e]	0.08	0.59
Methyl parathion	30[e]	2.5	1.1
Molinate	20[c]	8.9[d]	96[d]
Oxamyl	200[g]	0.14	0.27
Parathion	30[e]	0.25	1.83
Simazine	4[g]/10[c]	--	8.4
Thiobencarb	70[c]	<1.0[d]	4.9[d]

[a]As referenced in California Department of Water Resources, Compilation of Federal and State Drinking Water Standards and Criteria, July 1993.
[b]As presented in reports and data reviewed for and referenced in this Technical Memorandum.
[c]SMCL = State Maximum Contaminant Level.
[d]From 1987 through 1993.
[e]SAL = State action level.
[f]FMCL = Federal Maximum Contaminant Level.
[g]PFMCL = Proposed Federal Maximum Contaminant Level.

Over 2,400 analyses were conducted for 65 target pesticides and herbicides. In addition, samples were screened for pesticides detectable by mass spectrometry. Twenty-four of the 65 target pesticides and herbicides were detected a total of 94 times at or slightly above the detection level. All detected concentrations were below drinking water standards or California Department of Health Services (DHS) action levels (DWR, 1989).

DIDI. In 1988, DWR conducted the DIDI study to assess the impacts of Delta island agricultural drainage on the drinking water quality of Delta water. The focus of the DIDI study was THMFP. A synoptic study was done as part of the DIDI, to characterize pesticide occurrence. The pesticide monitoring plan was based on the same evaluation of factors as the IDHAMP monitoring plan.

The monitoring was conducted on 30 Delta agricultural drains in July 1988. Pesticides were largely not detected. Six pesticides (atrazine, bentazon, carbaryl, methamidophos, molinate, and simazine) were detected in a few drains. All concentrations of detected pesticides were below either drinking water standards or DHS action levels (DWR, 1990).

D-1485. DWR conducts monitoring for the D-1485 Delta salinity requirements at 29 telemetered stations in the Delta. The furthest stations upstream are the Sacramento River at Greene's Landing and the San Joaquin River at Vernalis. The monitoring program consists primarily of electrical conductivity measurements. Limited sampling is also conducted for nutrients, metals, and various pesticides. A review of the pesticide data from 1990 through 1992 indicates that pesticides are rarely detected. Diuron was detected at a few locations in 1991.

Water Hyacinth Control Program. Since the early 1980s, the DBW has controlled water hyacinths in the Delta channels and sloughs through the direct application of 2,4-D. The application of 2,4-D to control water hyacinths also occurs in the San Joaquin River system during the summer when there is insufficient flow to keep the waterways clear. In the San Joaquin River system, 2,4-D is applied to the San Joaquin River as far upstream as Merced County and to Salt Slough, the Merced River, and the Tuolumne River. At the request of the Regional Board, the DBW conducts periodic monitoring for 2,4-D, before, during, and after application. The DBW database is poorly organized; it is difficult to determine where the samples were collected and difficult to interpret the data. Concentrations of 2,4-D have not been detected above drinking water standards. Not infrequently, pre-application samples contain higher concentrations of 2,4-D (about 10 µg/l) than post-application samples (Personal Communication, Rudy Schnagl, Regional Board).

Delta Tributary Monitoring Programs

These studies, conducted in the Delta tributaries, focus primarily on ambient conditions with respect to biological resources rather than on drinking water quality.

National Stream Quality Accounting Network. The United States Geological Survey (USGS) conducts routine water quality monitoring at various locations in the San Joaquin and Sacramento River systems. Routine water quality monitoring stations are the Sacramento River at Freeport, the Mokelumne River at Woodbridge, and the San Joaquin River at Vernalis. The overall focus of this USGS monitoring program is general chemistry. Of the three sites listed above, the USGS has conducted synoptic pesticides monitoring only on the San Joaquin River at Vernalis.

Synoptic monitoring was conducted in the San Joaquin River at Vernalis in the fall of 1985 and again in 1988. In 1985, the USGS analyzed for 51 organic chemicals at Vernalis. Detection levels ranged from 1 to 3 µg/l. No pesticides were detected in the water samples. In the fall of 1988, the USGS analyzed for 35 organic chemicals at detection levels from 0.001 to 0.1 µg/l. Pesticides detected at or just above the detection level included cyanizine, DDE, DDT, diazinon, dieldrin, ethion, lindane, methyl parathion, metachlor, and parathion (USGS, 1985-1992).

In the fall of 1985, the USGS conducted synoptic pesticides monitoring of bed sediments and suspended sediments in the San Joaquin River system. The results of the study indicated DDD, DDE, DDT, and dieldrin are widespread in bed sediments of the San Joaquin River

System. The highest concentrations occurred in the westside tributary streams, sloughs, and drains (Gilliom and Clifton, 1990).

San Joaquin River Bioassay Study. The Regional Board conducted periodic surveys from 1988 through 1990 for toxicity to *Ceriodaphnia* at various locations in the San Joaquin River system. The purpose of the study was to determine whether river toxicity occurred and if so, whether it was associated with agricultural practices. Repeated toxicity was found in the San Joaquin River between the confluence of the Merced and Stanislaus rivers. Detected pesticides included diazinon, methyl parathion, carbaryl, dimethoate, and carbofuran (Foe and Connor, 1991b). The two suspected sources were: (1) dormant spray pesticide application to orchards, and (2) pesticide application to alfalfa for weevil control.

San Francisco Estuary Toxic Contaminants Program. This program is an umbrella program conducted by the USGS which has been examining pesticide input, transport, and fate to the San Francisco Estuary. Monitoring has been conducted since 1990 on the Sacramento River at Sacramento and the San Joaquin River at Vernalis. Many of the state agency programs have been conducted in coordination with this program. Pesticide monitoring has focused on rice pesticides (molinate, thiobencarb, and carbofuran), orchard runoff (diazinon, methidathion, chlorpyrifos, and carbaryl), and alfalfa runoff (carbofuran and simazine). Currently, related data have been published by the state agency studies which have been conducted in coordination with the USGS program. (Personal Communication, Kathryn Kuivila, USGS). The USGS has published information on three monitoring studies conducted under this program: the Pesticide Tracer Study and Rice Pesticides Transport Study, both discussed later in this section, and a study conducted in 1991 in San Francisco Bay to examine the percent of pesticides in the dissolved form versus that sorbed onto suspended sediment.

San Joaquin River Study. The DPR, in coordination with the Regional Board and the USGS, conducted a two-year monitoring study at 18 sampling locations on both the major tributaries and the main stem of the San Joaquin River (from Stevinson to Vernalis). Monitoring was conducted from 1991 through 1993. Frequently detected pesticides were diazinon, methidathion, and chlorpyrifos in the winter, carbofuran in the spring, and dimethoate and methomyl in the summer. Data from the study are partially published in a series of memoranda (Ross, 1991; 1992a; 1992b; 1993a; 1993b; 1993c). DPR is now evaluating best management practices (BMP) to reduce diazinon in orchard runoff. BMPs being evaluated involve cultural practices such as planting vegetative strips between orchard rows to increase soil permeability. (Personal Communication, Lisa Ross, DPR).

Winter Wheat Study. The DPR conducted a monitoring study for herbicides used on winter wheat crops in 1992. The study involved twice-weekly monitoring of the Colusa Basin Drain, Sutter Bypass, Feather River, and Sacramento River for 2,4-D, dicambra, and MCPA. All three herbicides were detected but at such low levels that no further study or mitigation was proposed. The data are not yet published. (Personal Communication, Pam Wofford, DPR).

Orchard and Alfalfa Study. In 1992, the Regional Board conducted a study of agricultural drainage from orchards and alfalfa crops. The purpose of the study was to determine (1) whether pesticides applied to orchards were causing toxicity in receiving waters (in the San Joaquin and Sacramento valleys), and (2) whether runoff from alfalfa fields causes toxicity in receiving waters.

The Orchard Study consisted of weekly monitoring of 11 sites in January and February 1992. Samples were collected during dry and wet weather. Six of the sites were small watercourses draining orchards. The other five sites were the Sacramento River above Colusa Basin Drain, the Feather River above the confluence with the Sacramento River, the Mokelumne River above the confluence with the Cosumnes River, the San Joaquin River at Bowman Road, and Old River. Thirty percent of the samples were toxic, primarily in the small watercourses. Samples collected during storm events were more toxic than those collected in dry weather. Pesticides detected in the toxic samples included diazinon, diuron, methidathion, bromacil, propham, and flumeturon.

The Alfalfa Study consisted of weekly monitoring of 13 sites in the Delta during March and April 1992. Samples were collected in dry weather only. Seven sites were small watercourses and six sites were in Delta sloughs. Thirteen percent of the samples were toxic.

Pesticides detected in the toxic samples included: diazinon, diuron, chlorpyrifos, and carbofuran (Foe and Sheipline, 1993).

National Water Quality Assessment Program. In 1991, the USGS initiated a water quality survey program of major river basins nationwide. The San Joaquin River was one of 20 river basins selected for study in 1991. The Sacramento River was one of 20 additional river basins selected for study in 1993. San Joaquin River monitoring was begun in 1992 and included general chemistry, nutrients, and pesticides. Monitoring in the Sacramento River Basin has not yet begun.

Monitoring for pesticides in the San Joaquin River Basin was conducted in Orestimba Creek, the Merced River, and the San Joaquin River at Vernalis. The sampling period was April through September 1992 and December 1992 through February 1994. Monitoring frequency varied between three times a week to once a month, depending on the sampling location and the season. A preceding literature review led to a pesticide sampling scheme based on winter, spring, and summer pesticide usage. The surface water pesticide monitoring is complete and the study will next address the relationship between pesticides, crop types (grapes and almonds), and groundwater contamination. Frequently detected pesticides included diazinon (in the winter and summer) and chlorpyrifos and methidathion in the spring. Frequently detected herbicides included simazine, triazine, and metolachlor. These data are not yet published. (Personal Communication, Joe Domagalski, USGS).

Pesticide Tracer Study. The USGS conducted a tracer study of pesticide transport from the Sacramento and San Joaquin River systems through the Delta. The study was conducted in cooperation with the Regional Board as part of the San Francisco Bay-Estuary Toxic Contaminants Study. The purpose was to characterize orchard dormant pesticide spray fate and transport. The monitoring plan was designed to catch storm runoff events following the annual winter dormant pesticide spray applications to orchards. Dormant pesticide sprays were applied to many Central Valley orchards during two weeks of dry weather in January 1993. Storm events in early February 1993 were then monitored. The monitoring was specifically designed to follow storm discharges through the Sacramento and San Joaquin River systems. Monitoring locations were the Sacramento River at Sacramento, Rio Vista, and Chipps Island; the San Joaquin River at Vernalis and Stockton; and the Carquinez Straight at Martinez.

Dissolved diazinon in storm runoff moved through the river systems (with a time lag of one to three days following storm events) until mixed and dissipated by sea water in San Francisco Bay. The maximum concentration detected was 1,070 ng/l in the San Joaquin River at Vernalis. The Regional Board conducted seven-day *Ceriodaphnia* bioassay tests on the sample water. River samples before and after the storm transport of diazinon were not toxic. During the storm runoff transport, the river water produced 100 percent mortality. Other analyses on the storm runoff river water showed the presence of additional pesticides: chlorpyrifos, methidathion, and carbaryl (Kuivila, 1993).

Rice Field Drainage. Water quality monitoring and toxicity testing in rice field agricultural drains conducted as part of the State's interagency Rice Pesticide Control Program are discussed in this section. There is also a discussion of how these and other studies have resulted in performance goals and management practices for five pesticides found in rice drainage.

<u>Rice Field Drainage Pesticide Chemistry Monitoring</u>. Pesticide monitoring has been conducted in rice growing area agricultural drains (principally Colusa Basin Drain, Butte Slough, and Sacramento Slough) and in the Sacramento River near Sacramento by the California Department of Fish and Game (DFG) since 1980 (Finlayson, et al; 1982, 1983, 1984, 1985, 1986, 1991, 1993; Harrington and Lew, 1988; DPR, 1984-1993). Results for each pesticide are summarized below.

Molinate (Ordram). The peak concentration of molinate in an agricultural drain was measured at 357 µg/l in 1981. A steady reduction in concentrations occurred between 1981 and 1986. From 1987 through 1993, peak concentrations have ranged between 6.2 and 96 µg/l. In the Sacramento River, the peak concentration of molinate was measured at 27 µg/l in 1982. The reduction in agricultural drainage concentrations has resulted in a corresponding reduction in river concentrations between 1982 and 1986. From 1987 through 1993 peak concentrations in the river have ranged from <1.0 to 8.9 μg/l.

Thiobencarb (Bolero). The peak concentration of thiobencarb in an agricultural drain was measured at 170 μg/l in 1982. A steady reduction in concentrations occurred between 1982 and 1986. From 1987 through 1993, peak concentrations have ranged between <1.0 and 4.9 μg/l. In the Sacramento River, the peak concentration of thiobencarb was measured at 6 μg/l in 1982. From 1987 through 1993, the concentration in the river has been <1.0 μg/l.

Carbofuran (Furadan). This pesticide was monitored in agricultural drains between 1988 and 1993 with concentrations ranging from <1.0 to 4.4 μg/l. In 119 samples collected from the Sacramento River during this time period, carbofuran has been detected three times. The peak concentration in the river was measured at 0.6 μg/l.

Bensulfuron methyl (Londax). This pesticide was monitored in agricultural drains from 1989 through 1993. Detected concentrations have been highly variable, ranging from <0.5 to 210 μg/l. In 27 samples collected from the Sacramento River during this time period, bensulfuron methyl was not detected (detection limit 0.5 μg/l).

Malathion. This pesticide was monitored between 1990 and 1993 in agricultural drains. The measured concentrations are mostly <0.10 μg/l. The peak concentration measured was 0.59 μg/l. In 43 samples collected from the Sacramento River during this time period, malathion was not detected (detection level 0.10 μg/l).

Methyl parathion. This pesticide was monitored between 1990 and 1993 in agricultural drains. The measured concentrations are mostly <0.10 μg/l. The peak concentration measured was 1.1 μg/l. In 43 samples collected from the Sacramento River during this time period, methyl parathion was not detected (detection limit 0.10 μg/l).

Propanil. This pesticide was monitored in an agricultural drain in 1987. The pesticide was detected once in 12 samples, at a concentration of 1.6 μg/l. All other samples were <0.5

μg/l. In 12 samples collected from the Sacramento River during this period, propanil was not detected (detection limit 0.5 μg/l).

Carbaryl. This pesticide was monitored three times in an agricultural drain in 1987. It was not detected at a detection limit of 0.1 μg/l. Carbaryl was not detected in the three samples collected from the Sacramento River during this time period (detection limit 0.1 μg/l).

Rice Field Drainage Toxicity Testing. The Regional Board and DFG conducted toxicity testing in several rice field drains from 1986 through 1989. This work was part of an overall toxicity assessment of the Sacramento River. Toxicity was known to occur in the river upstream of the rice cultivation area (attributed to mine drainage). The goal of this study was to determine whether rice drainage also contributed to toxicity in the Sacramento River.

Toxicity testing was conducted in May and June during the initial release of herbicide treated water from rice fields and also at several other times of year. The testing occurred in Colusa Basin Drain, Butte Slough, and Sacramento Slough, three of the principal rice area agricultural drains. The study concluded that rice drainage is frequently toxic to aquatic life during May and June. The drainage was generally not toxic during other times of the year. Pesticides detected in toxic samples were:

1986 - methyl parathion, chlorpyrifos
1987 - methyl parathion, carbofuran, malathion
1988 - methyl parathion, carbofuran
1989 - methyl parathion, carbofuran, malathion

Toxicity during May and June was also found in the Sacramento River as far downstream of the rice fields as Rio Vista.

Additional toxicity testing was conducted by the DFG and the Regional Board in April through June of 1990. Toxicity testing and chemistry monitoring were conducted three times a week on Colusa Basin Drain. This work identified the specific toxicant as methyl parathion.

This work resulted in proposed changes in management practices for the use of methyl parathion on rice fields (Foe and Connor, 1991a).

Rice Pesticides Transport Study. In June 1990, the USGS monitored a "parcel" of water moving through the Sacramento River system from below Colusa Basin Drain to Rio Vista. The parcel was sampled every 6 hours for molinate, thiobencarb, carbofuran, and methyl parathion. The results indicated a slight decreasing trend in molinate concentrations from upstream to downstream but no recognizable decrease in thiobencarb or carbofuran concentrations. Methyl parathion degradation products were detected in the parcel, but not methyl parathion (Domagalski and Kuivila, 1991).

Other Studies, Performance Goals, and Management Practices. The DPR and the Regional Board conducted a study in April 1991 to determine whether drift from aerial spraying is a significant factor in methyl parathion concentrations in rice field drainage water. Methyl parathion is applied to control tadpole shrimp. Four agricultural drainage ditches in Colusa County were sampled before and after aerial spraying. The results suggested that methyl parathion levels may increase when the flight path parallels the drainage ditch (Pino, et al, 1992). Future monitoring efforts will involve a study of whether seepage through levees is a significant factor in pesticide concentrations in the canals.

The DFG is in the process of conducting a hazard assessment of various pesticides with respect to their effects on aquatic life. The proposed use of the hazard assessment will be to provide the Regional Board with criteria for pesticides which the DFG believe are acceptable in terms of the impact on the aquatic habitat. These criteria are considered in the Regional Board's annually established Performance Goals (Personal Communication, Rudy Schnagl, 1994).

The DPR began their rice herbicide control program in 1983 - focused primarily on molinate and thiobencarb. In 1990, the Regional Board adopted a Basin Plan Amendment which set performance goals for five pesticides in agricultural drainage. The performance goals are reviewed annually. The 1993 performance goals are:

Carbofuran	0.4 µg/l
Malathion	0.1 µg/l
Methyl parathion	0.13 µg/l
Molinate	10 µg/l
Thiobencarb	1.5 µg/l

The discharge of agricultural drainage containing these pesticides is prohibited unless the discharger is following appropriate management practices. Rice field agricultural drainage water quality has moved closer to, but often does not meet, these performance goals. Factors that affect the concentrations include weather (pesticides dissipate more quickly under warmer temperatures), drought conditions (although there is less available dilution, there is also generally less discharge and less total mass of pesticides discharged), and emergency releases (releases made to protect crops before holding times are completed).

The appropriate management practice for carbofuran is that pre-flood applications must be incorporated into the soil. The management practice for the other four pesticides listed above involves retaining the treated water on the field for varying degrees of time. Management practices that were added for the 1993 growing season include a 100-foot buffer zone next to canals on the downwind side of aerial applications and actively discouraging emergency releases. These management practice programs are implemented through the County Agricultural Commissioners (Lee and Gordner, 1993).

There is a Memorandum of Understanding between the Regional Board and the DPR to coordinate their efforts on pesticides registration, studies, and monitoring efforts. Currently, a Management Agency Agreement is being discussed which would give the Regional Board significant input to the selection and prioritization of pesticides to be monitored (Personal Communication, Rudy Schnagl, 1994).

Review of Nine Pesticides. In 1993, the Regional Board assembled information on nine pesticides detected in Central Valley surface waters which Regional Board staff believe contribute to aquatic toxicity. The information is summarized in Table 3 (Sheipline, 1993).

Table 3. Pesticides Which May Contribute to Aquatic Toxicity in Central Valley Surface Waters

Chemical name	Trademark name	Type of pesticide	Range of concentration detected in Central Valley surface waters, µg/l	Criteria, µg/l	Persistence in surface waters	Usage	Months used	Counties with highest application
Carbaryl	Sevin	Carbamate insecticide	0.6 to 8.4	0.02[a]	1.3 to 5.8 days	Row crops Orchards Landscapes	January through December	Tulare Kern Fresno
Methomyl	Lannate	Carbamate insecticide	0.06 to 5.4	None	Unknown	Row crops Field crops Citrus orchards	March through October	Fresno Kern Tulare
Oxamyl	Vydate	Carbamate insecticide	0.12 to 0.14	None	Unknown	Row crops Orchards	May through August	San Joaquin Merced Stanislaus
Chlorpyrifos	Dursban Lorsban	Organophosphate insecticide	0.01 to 1.6	0.041[b]	7.1 to 53 days	Orchards Row crops Field crops Landscapes Structures	January through December	Tulare Fresno Kern
Diazinon	Basudin Diazitol	Organophosphate insecticide	0.02 to 6.84	0.009[a]	12 hours to 6 months	Orchards Row crops Field crops Landscapes Structures	January through December	Fresno Kern Merced
Dimethoate	Cygon Perfekthion Roxion Fostion Rogor	Organophosphate insecticide	0.05 to 1.05	None	8 weeks	Orchards Row crops Field crops	May through August	Tulare Kern Fresno
Fonofos	Dyfonate	Organophosphate insecticide	0.01 to 0.54	None	12 to 127 days	Row crops	April	San Joaquin Sacramento Stanislaus
Methidiathon	Supracide Ultracide	Organophosphate insecticide	0.14 to 15.1	None	Unknown	Orchards Field crops	November through September	Tulare Fresno Kings Kern
Diuron	Karmex	Urea herbicide	0.1 to 30.6	1.6[a]	Unknown	Orchards Field crops Landscape	January through December	Tulare Fresno Kern San Joaquin

Source: Sheipline, Robert. Background Information on Nine Selected Pesticides. California Regional Water Quality Control Board, Central Valley Region. Draft Staff Report. Septebmer 1993.
[a]National Academy of Sciences recommended maximum in surface waters.
[b]EPA 4-day freshwater criteria.

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Four Rivers Project. The DPR and DFG are initiating a year-long pesticide monitoring program on four California rivers. The Sacramento and Merced rivers are in the Delta watershed. The other rivers are the Russian and Salinas rivers. The monitoring will consist of weekly pesticide chemistry testing and toxicity testing every two weeks. Sacramento River monitoring (at Sacramento) began in the fall of 1993. Monitoring on the Merced River has not yet begun. No data are published or available. (Personal Communication, Robert Fujimura, DFG).

Sacramento Ambient Monitoring Program. The City of Sacramento, the Sacramento County Water Agency, and the Sacramento Regional County Sanitation District began biweekly ambient monitoring in the American and Sacramento rivers in 1993. In 1994, organophosphorus pesticide monitoring will be added to the list of constituents sampled. The City and County of Sacramento are Co-permittees in a National Pollutant Discharge Elimination System (NPDES) Stormwater Permit. The impetus for this additional analysis is the concern, based on recent Regional Board work, that urban stormwater runoff may be contributing pesticides to receiving waters in concentrations toxic to aquatic life.

Sacramento Urban Runoff Toxicity Studies. The Regional Board and the Sacramento Stormwater NPDES Permittees are conducting studies to determine the chemicals responsible for aquatic toxicity in urban runoff. Toxicity testing was conducted during two storm events in 1993 and one storm event in 1994 in a total of 21 Sacramento and Stockton urban runoff discharges and urban creeks and sloughs. *Ceriodaphnia* toxicity was seen in all urban runoff discharge samples and most urban creeks and sloughs. The results indicate that organophosphorus pesticides are the likely toxicants and that diazinon is the primary toxicant. The highest concentration of diazinon measured was 1.1 µg/l. Additional toxicants appear to be present but have not yet been identified (Connor, 1994). The study will likely continue during the 1994/1995 rain season. The Regional Board is currently conducting a survey on diazinon in dry weather urban runoff.

The Regional Board is proposing to conduct a study on diazinon occurrence in atmospheric dry deposition and rainfall. The Bay Area Regional Board is proposing to conduct a study to identify the most significant diazinon sources in urban watersheds and develop corresponding source control measures (Personal Communication, Valerie Connor, 1994).

OVERALL RESULTS RELEVANT TO THIS STUDY

This section discusses the pesticide data collected in the Delta and Delta tributary watersheds with respect to (1) its effect on the drinking water quality of the Delta and the Delta tributaries, (2) its relevance with regard to loads calculations for this study, and (3) an assessment of the need for additional pesticide monitoring.

Pesticides with significant agricultural or urban applications in the Delta tributary watersheds are detected in the river system. No pesticides have been detected in the rivers at concentrations above drinking water standards. With the exceptions of occasional molinate concentrations in rice field drainage and diazinon concentrations in San Joaquin River westside drains, no pesticide has been detected in a drain at concentrations above drinking water standards. In general, pesticide concentrations are at least an order of magnitude lower than drinking water standards. These concentrations, while apparently not a threat to human health, are of considerable concern to aquatic life and are considered responsible for some of the toxicity found in Delta tributary rivers.

Although pesticides are not detected at concentrations above drinking water standards, their presence in the sources of drinking water is of concern for several reasons. First, some pesticides are detected for which there are no drinking water standards. For these pesticides, it is less clear that the concentrations are too low to adversely affect human health. Second, although individual pesticides are detected well below drinking water standards, the possible synergistic effects of several pesticides present in the drinking water is not well known. Third, there is a public perception that pesticides should not be present in drinking water, regardless of the concentrations. Finally, water supplies taken from the Delta and Delta tributaries are in jeopardy, particularly during dry years, due to the decline in the ecological resources of the

Bay/Delta system. Pesticides may be partially responsible for the decreased populations of fish and other aquatic organisms.

Pesticides are not recommended for inclusion in the calculations of loads for this study. Although there has been considerable pesticide monitoring conducted, it appears that pesticide concentrations are extremely episodic due both to "pesticide seasons" based on agricultural crop practices and the timing of the application relative to storm events. The calculation of mass loads based on grab samples, therefore, may be particularly nonrepresentative. In addition, there are more significant constituents (relative to drinking water) for inclusion in the calculation of mass loads. With respect to the study of various control alternatives, however, it seems apparent that effective control of agricultural (and to a less extent, urban runoff) discharges would reduce the loads of pesticides into the Delta tributaries.

No additional pesticide monitoring is recommended for this study. There are two major upcoming areas of monitoring which will provide additional pesticide data for future evaluation regarding pesticides in drinking water. The first is the continuing work being done by the USGS and various state agencies (Regional Board, DPR, and DFG) regarding the identification and control of pesticides which affect aquatic life. The second is the upcoming work that water utilities will need to conduct to comply with the Phase II/V Regulations. This will involve some combination of a "vulnerability assessment," which looks in more detail at specific regulated organic chemical usage in a water utility's watershed, and/or monitoring at the utility's intake.

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