Dissolved Pesticide Concentrations Detected in Storm-Water Runoff at Selected Sites in the San Joaquin River Basin, California, 2000–2001

By James L. Orlando, Kathryn M. Kuivila, and Andrew Whitehead

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CONVERSION FACTORS AND SYMBOLS

CONVERSION FACTORS

Multiply	By	To obtain
kilogram (kg)	2.205	pound avoirdupois
kilometer (km)	0.6214	mile
liter (L)	33.82	ounce, fluid
meter (m)	1.094	yard
square kilometer (km^2)	247.1	acre

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8.

ABBREVIATIONS

BML	Bodega Marine Laboratory
GC/MS	gas chromatography-mass spectrometry
mL	milliliter
ng/L	nanogram per liter
USGS	U.S. Geological Survey

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ABSTRACT

As part of a collaborative study involving the United States Geological Survey Toxics Substances Hydrology Project (Toxics Project) and the University of California, Davis, Bodega Marine Laboratory (BML), water samples were collected at three sites within the San Joaquin River Basin of California and analyzed for dissolved pesticides. Samples were collected during, and immediately after, the first significant rainfall (greater than 0.5 inch per day) following the local application of dormant spray, organophosphate insecticides during the winters of 2000 and 2001. All samples were collected in conjunction with fish-caging experiments conducted by BML researchers. Sites included two locations potentially affected by runoff of agricultural chemicals (San Joaquin River near Vernalis, California, and Orestimba Creek at River Road near Crows Landing, California, and one control site located upstream of pesticide input (Orestimba Creek at Orestimba Creek Road near Newman, California). During these experiments, fish were placed in cages and exposed to storm runoff for up to ten days. Following exposure, the fish were examined for acetylcholinesterase concentrations and overall genetic damage. Water samples were collected throughout the rising limb of the stream hydrograph at each site for later pesticide analysis. Concentrations of selected pesticides were measured in filtered water samples using solid-phase extraction (SPE) and gas chromatography-mass spectrometry (GC/MS) at the U.S. Geological Survey organic chemistry laboratory in Sacramento, California. Results of these analyses are presented.

INTRODUCTION

The land and water resources of California's San Joaquin River Basin help support the nation's most productive agricultural economy. The counties of the San Joaquin River Basin produced a variety of crops worth over 8.3 billion dollars in the year 2000 (California Department of Food and Agriculture, 2001). Important crops that are grown in this region include almonds, apricots, cherries, peaches, and walnuts. Organophosphates and other types of pesticides are applied to these orchards during dormancy to control wood-boring insects. Application of pesticides during the December–February dormant spray season coincides with the region's peak annual rainfall. Previous studies have shown that, for areas within the basin, the first significant rainfall and runoff following the winter application of organophosphate insecticides is accompanied by a rise in the detected concentrations of these same pesticides in downstream surface waters (Kuivila and Foe, 1995; Kratzer, 1997; Dubrovsky and others, 1998). Studies have also shown these pesticide pulses to be acutely toxic to certain aquatic invertebrates such as *Ceriodaphnia dubia* (Foe and Connor, 1991; Kuivila and Foe, 1995). However, little is known concerning the potential effects of these pulses on fish.

In 1999, the U.S. Geological Survey (USGS) Toxics Project began a collaborative study with researchers from the U.C. Davis Bodega Marine Laboratory (BML) that focused on an examination of

the physical and genetic responses to pesticides of the native California fish species, *Catastomus occidentalis*, under both field and laboratory conditions. Field experiments exposing *C. occidentalis* to storm-water runoff at three locations in the San Joaquin River Basin (fig. 1) were conducted in the winters of 2000 and 2001. During these experiments, fish were placed in cages and exposed to in-stream conditions for periods ranging from one to ten days, beginning prior to the onset of the first significant rainfall and runoff following the local application of dormant spray pesticides, and extending through the rising limb of the stream hydrograph at each site. Water samples were collected throughout the exposure periods for pesticide analysis, and laboratory fish-exposure studies. Following exposure in the field, fish were dissected and samples of blood and tissue were collected and analyzed at BML for acetylcholinesterase concentrations and overall genetic damage.

Purpose and Scope

As part of this study, the Toxics Project was responsible for a number of field and analytical tasks. These tasks included the selection of sampling sites, initiation of field experiments, collection of water samples for lab exposures and water quality analysis, and analysis of all water samples for dissolved pesticides. This report describes the sampling sites chosen and the methods and procedures used during water sample collection and analysis. Dissolved pesticide concentrations analyzed in water samples collected during this study are presented.

Acknowledgments

The authors gratefully acknowledge G. Edward Moon, of the USGS Toxics Project as well as other USGS personnel for help with sample collection and logistical support during this project. The authors also wish to acknowledge Jacqueline Houston and Theresa Pedersen of the USGS for their many hours of laboratory work and pesticide analyses. This project was funded by the USGS Toxics Substances Hydrology Program and by a grant from the U.S. Environmental Protection Agency (R-826603-01-0).

STUDY DESIGN AND METHODOLOGY

Selection of Sampling Sites

Three sites were chosen in the San Joaquin River Basin for combined fish exposure studies and pesticide analysis (fig. 1; table 1). Sites were selected on the basis of local agricultural practices, past and current use of organophosphate insecticides, previous surface-water detections of organophosphate insecticides, suitability for fish caging, and safety of field personnel during storm conditions. Using these criteria, two sites potentially affected by insecticides were chosen: San Joaquin River near Vernalis, California (or "Vernalis"), and Orestimba Creek at River Road near Crows Landing, California (or "Orestimba"). In addition, a single control site located upstream of potential pesticide input, Orestimba Creek at Orestimba Creek Road near Newman, California (or "Upper Orestimba") was chosen (fig. 1). All three sites are located in proximity to active USGS gaging stations.

Vernalis is located at the basin outlet of the San Joaquin River watershed and receives runoff from approximately 19,002 km^2 of land in the Sierra Nevada, the San Joaquin Valley, and the Coast Ranges. Land use at lower elevations is principally agricultural and urban, while higher elevations are dominated by forest and woodland. This site has a long history of water-quality monitoring by numerous state and federal agencies. Previous studies have detected diazinon at concentrations in excess of 1,000 ng/L in water samples collected at this site (Kuivila and Foe, 1995). Orestimba is located approximately 1.5 km upstream from the confluence of Orestimba Creek and the San Joaquin River and represents a watershed of approximately 603 km^2 in the San Joaquin Valley and the Coast Ranges. Land use in the vicinity of this site is predominantly agricultural. High concentrations of agricultural chemicals have been detected at this site in previous years (Panshin and others, 1998). Upper Orestimba is located 19 km upstream of Orestimba, at the edge of the Coast Ranges. The drainage area above this site is approximately 332 km^2. Vegetation upstream of the sampling site is mostly woodland with little or no agriculture.

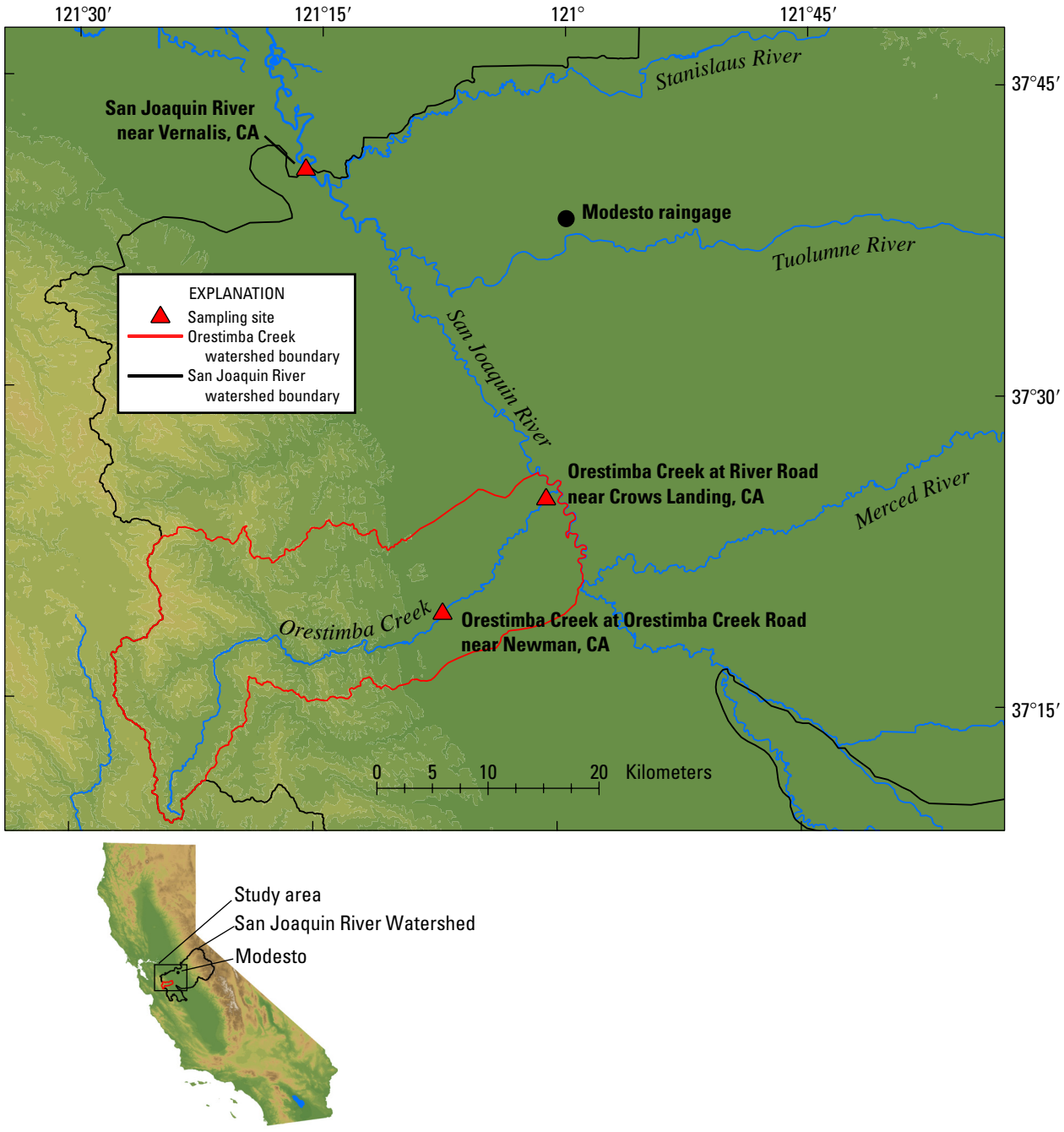

Figure 1. Location of study area and sampling sites in the San Joaquin Valley, California.

Table 1. Pesticide sampling sites, San Joaquin River Basin, California

[ID, identification; USGS, U.S. Geological Survey; km, kilometer]

Site name	USGS site ID number	Latitude	Longitude	Description
Orestimba Creek at Orestimba Creek Road near Newman, California (Upper Orestimba)	371912121071201	37°19′09″	121°07′15″	Located 19 km upstream of Orestimba, at the edge of the Coast Ranges
Orestimba Creek at River Road near Crow's Landing, California (Orestimba)	11274538	37°24′51″	121°00′54″	Located 1.6 km upstream of confluence with San Joaquin River
San Joaquin River near Vernalis, California (Vernalis)	11303500	37°40′33″	121°15′55″	Basin outlet for the San Joaquin River watershed

Generalized Sampling Methods

Field experiments were initiated just prior to the first significant rainfall (>0.5 in./day) and runoff following the local application of dormant spray pesticides in 2000 and 2001. Fish cages were emplaced at each of the sites under prestorm streamflow conditions and exposed throughout the rising limb of the stream hydrograph (figs. 2 and 3). This sequence of events was chosen to ensure the exposure to maximum concentrations of dissolved pesticides associated with initial storm runoff from upstream agriculture. Water samples for pesticide analysis and laboratory exposures were collected over the same time periods, but under varying schedules depending on the hydrologic characteristics of the individual watersheds.

All samples were collected as surface grabs by one of three methods. At Vernalis and Orestimba, samples were collected from a bridge as mid-channel surface grabs or by pumping. At Upper Orestimba, all samples were collected as mid-channel grabs or from the shore. All water samples were collected in proximity to the fish exposure cages at each site and at a depth of 0.5 m beneath the water surface. Streamflow at each site was likely well mixed, with the exception of the Upper Orestimba in 2001.

Sampling Methods at the Three Sites

Vernalis

Water samples were collected over a period of nine consecutive days (2/11/00–2/19/00) in 2000 (fig. 2) and seven consecutive days (1/26/01–2/01/01) in 2001 (fig. 3). Additional samples were collected during the emplacement and removal of individual fish cages. Samples were obtained either by pumping directly into 1-L amber glass bottles using a peristaltic pump equipped with a single stainless steel and Teflon inlet hose suspended in mid-channel, or as single mid-channel grabs using a weighted 3-L Teflon bottle sampler from a bridge.

Orestimba

In both years, sampling took place in two stages: an initial intensive period during which samples were collected hourly over approximately 24 hours, followed by daily sampling for a period of six consecutive days (figs. 2 and 3). Additional samples were collected in 2001 during the emplacement and removal of individual fish cages. During the initial hourly sampling, water was collected using a peristaltic pump with a single stainless steel and Teflon inlet hose suspended in the center of flow. Samples were pumped directly into 1-L amber glass bottles. For the 2000 sampling period, daily water samples were collected using a weighted two-bottle sampler, which consisted of a 7-kg brass sounding weight modified to hold two 1-L amber glass bottles. During 2001, daily samples were collected using a weighted 3-L Teflon bottle sampler and poured directly into 1-L amber glass bottles. A series of samples were collected January 24–27, 2000, in response to a storm that failed to produce significant runoff. This storm was considered a "false start," though the pesticide analyses are included in this report. A complete sampling and field caging was conducted in mid-February following a much stronger winter storm.

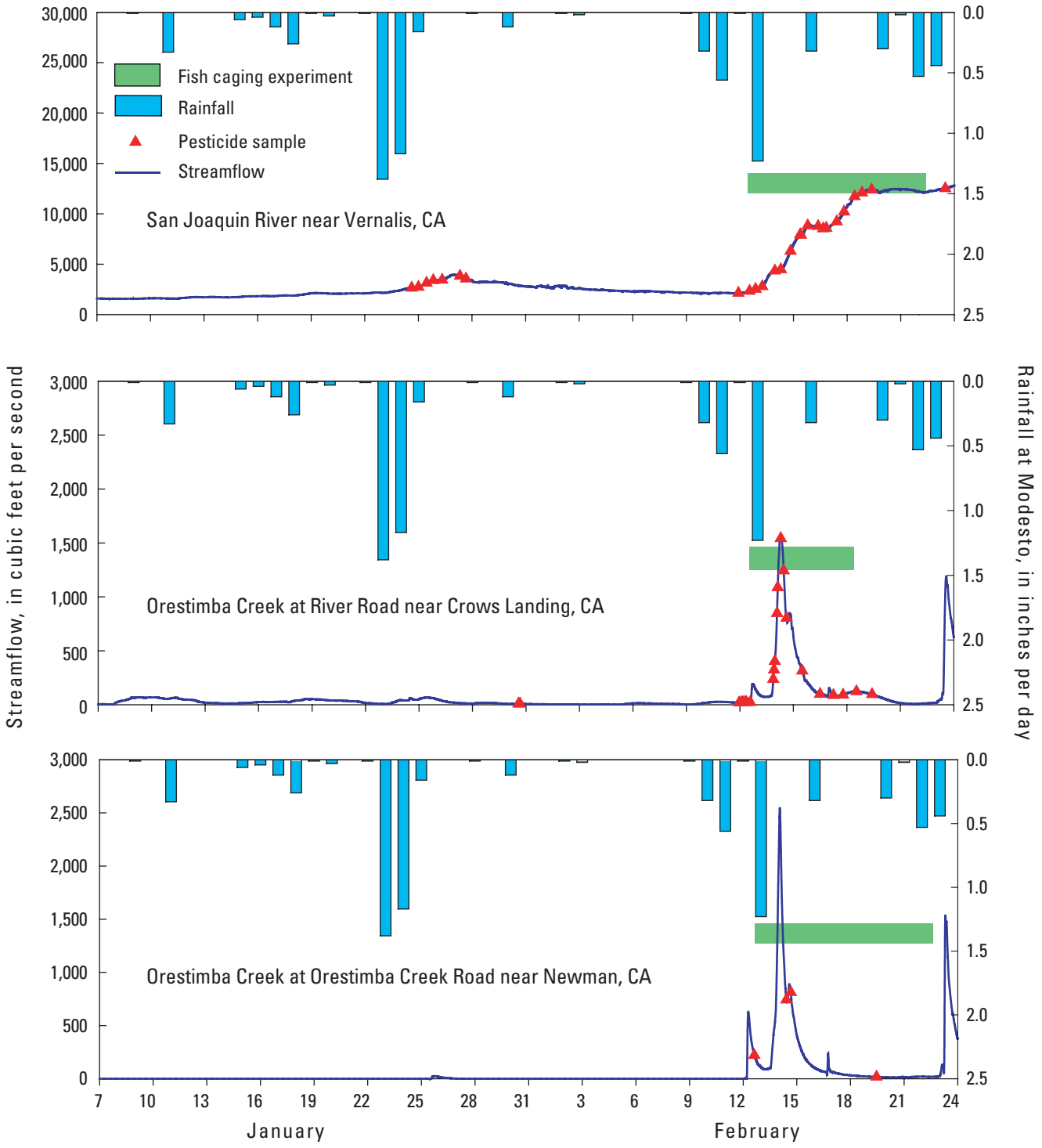

Figure 2. Sample collection times for the year 2000, fish caging experiment durations, streamflow at the collection site, and rainfall at Modesto, California.

Streamflow data collected at USGS site 11274500 Orestimba Creek near Newman, California.

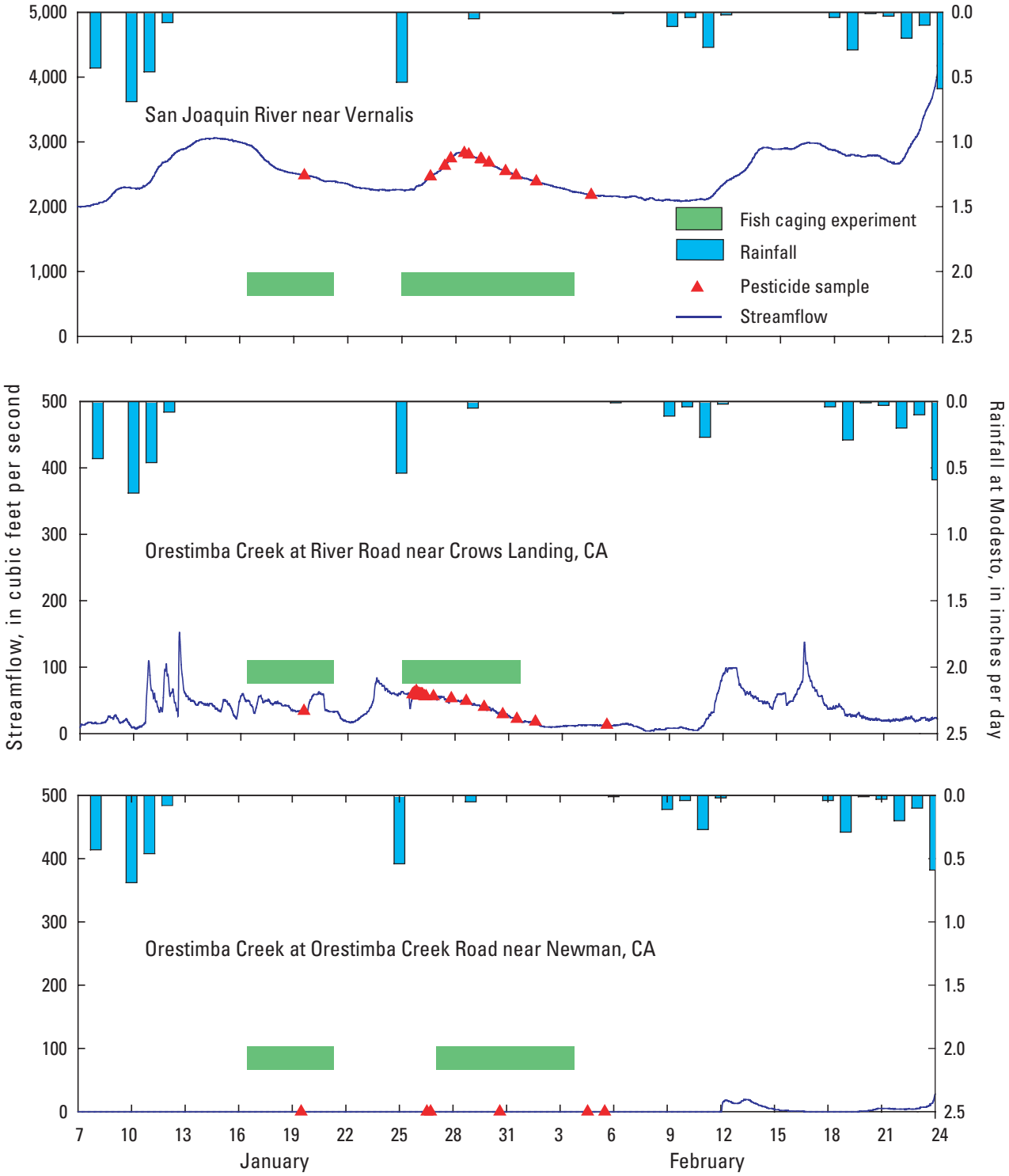

Figure 3. Sample collection times for the year 2001, fish caging experiment durations, streamflow at the collection site, and rainfall at Modesto, California.

Streamflow data collected at USGS site 11274500 Orestimba Creek near Newman, California.

Upper Orestima

As a control, samples were collected at times corresponding to the beginning, middle, and end of the sampling periods of the other two sites. In 2000, all samples were collected at a point near the center of flow using a weighted two-bottle sampler. Because of very light rainfall in the upper reaches of the watershed during the 2001 sampling period, no appreciable surface flow occurred at this site. However, samples were collected from a large, permanent, in-channel pool located approximately 100 m downstream from the standard collection site. Samples were collected at times corresponding to the emplacement and removal of fish cages by submerging 1-L amber glass bottles to a depth of 0.5 m for filling.

Sample Processing and Analysis

Collected water samples were preserved on ice and, within 24 hours, filtered through baked, 0.7 micrometer glass-fiber filters. A surrogate compound, terbuthylazine, was added to provide quantitative data on extraction efficiency, and the samples were then extracted using C8 solid-phase extraction cartridges. The cartridges were then dried using a syringe to repeatedly force air through each cartridge, frozen, and delivered to the USGS organic chemistry laboratory in Sacramento, California, where they were stored frozen for up to six months. Once removed from storage, each cartridge was eluted with 9 mL ethyl-acetate and analyzed by gas chromatography-mass spectrometry (GC/MS). Samples collected in 2000 were analyzed for 26 individual pesticides, whereas in 2001, the total was 31 pesticides.

Four types of quality-control data were collected: field and laboratory equipment blanks, replicate samples, matrix spikes, and surrogate recovery. Equipment blanks were analyzed every 20–30 samples for a total of two blanks in 2000 and three in 2001. None of the pesticides were detected in the blanks. Replicate samples constituted 33 percent of the samples analyzed and were within 25 percent agreement for each of the pesticides detected. As part of the method validation, recoveries of matrix spikes were determined in 10 percent of the samples, and details are listed in the method reports (Kathryn Kuivila and Jacqueline Houston, USGS, Sacramento, California, unpub. data, 2002; Theresa Pedersen and Kathryn Kuivila, USGS, Sacramento, California, unpub. data, 2002). Recovery of the surrogate, terbuthylazine, was used to assess the efficiency of each extraction. The average percent recovery and standard deviation for terbuthylazine was calculated for each year. Sample data were excluded if the recovery of terbuthylazine was outside the control limit of the annual mean plus or minus two standard deviations (Kuivila and Houston, unpub. data, 2002; Pedersen and Kuivila, unpub. data, 2002).

DISSOLVED-PESTICIDE CONCENTRATIONS

This report presents dissolved-pesticide concentrations analyzed in water samples collected during storms in January–February 2000 and 2001. Samples were collected at three surface-water sites in conjunction with fish-caging studies (figs. 2 and 3). A total of 105 water samples were analyzed for 26 or 31 pesticides by GC/MS at the U.S. Geological Survey's organic chemistry laboratory in Sacramento, California. Results of these analyses are presented in tables 2, 3, and 4. Table 5 shows pesticide detection limits for the analysis methods used in 2000 and 2001. Pesticides that were detected at concentrations below the method detection limits listed in table 5 are shown in parentheses because the values are estimates.

Table 2. Pesticide concentrations in water samples collected at Orestimba Creek at Orestimba Creek Road near Newman, California, 2000–2001.

[Values are reported as nanograms per liter. Water samples were analyzed for the following pesticides that were not detected at this site: alachlor, atrazine, azinphos-methyl, butylate, carbaryl, cyanazine, cycloate, diethatyl-ethyl, eptam, ethalfluralin, fonofos, malathion, methylparathion, napropamide, pebulate, pendimethalin, phosmet, sulfotep, and thiobencarb. nd, nondetection; —, not analyzed; ( ), concentration below detection limit]

Date (mm/dd/yy)	Time	Carbo-furan	Chlor-pyrifos	Dacthal	Diazinon	Hexa-zinone	Methi-dathion	Meto-lachlor	Moli-nate	Oxy-fluorfen	Piper-onyl Butoxide	Sima-zine	Triflu-ralin
Sampling year 2000													
02/12/00	1440	nd	nd	nd	nd	—	nd	nd	nd	—	—	nd	nd
02/14/00	930	8.6	11.3	7.0	10.7	—	20.1	11.7	nd	—	—	14.1	16.5
02/14/00	1615	nd	nd	nd	nd	—	nd	nd	nd	—	—	nd	nd
02/19/00	1050	nd	nd	nd	nd	—	nd	nd	nd	—	—	nd	nd
Sampling year 2001													
01/19/01	1200	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
01/26/01	1245	nd	nd	nd	nd	nd	nd	nd	9.4	nd	nd	nd	nd
01/26/01	1745	nd	nd	nd	nd	10.0	nd	nd	nd	nd	(2.9)	nd	nd
01/30/01	1445	nd	nd	nd	nd	nd	nd	nd	14.9	nd	nd	nd	nd
02/04/01	1300	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	17.7
02/05/01	1200	nd	nd	nd	12.0	17.3	nd	nd	nd	23.2	16.2	26.1	19.1

Table 3. Pesticide concentrations in water samples collected at Orestimba Creek at River Road near Crows Landing, California, 2000–2001

[Values are reported as nanograms per liter. Water samples were analyzed for the following pesticides that were not detected at this site: alachlor, azinphos-methyl, carbofuran, cyanazine, fonofos, malathion, methylparathion, napropamide, pebulate, phosmet, sulfotep, and thiobencarb. nd, nondetection; —, not analyzed; ( ), concentration below detection limit]

Date (mm/dd/yy)	Time	Atrazine	Butylate	Carbaryl	Chlorpyrifos	Cycloate	Dacthal	Diazinon	Diethatyl-ethyl	Eptam
					Sampling year 2000					
01/30/00	1425	nd	nd	nd	nd	nd	nd	9.7	nd	nd
01/30/00	1625	nd	nd	nd	nd	nd	nd	nd	nd	nd
02/11/00	2335	nd	nd	nd	nd	nd	nd	24.4	nd	nd
02/12/00	135	nd	nd	nd	nd	nd	17.2	24.5	nd	nd
02/12/00	300	11.4	nd	nd	nd	nd	nd	27.7	nd	nd
02/12/00	335	nd	nd	nd	nd	nd	nd	27.6	nd	19.3
02/12/00	630	nd	nd	nd	nd	nd	14.3	26.5	nd	nd
02/12/00	840	nd	nd	nd	nd	nd	15.5	25.1	nd	nd
02/12/00	1340	nd	nd	nd	nd	nd	nd	22.9	nd	16.8
02/13/00	2055	nd	nd	nd	nd	nd	nd	46.3	nd	nd
02/13/00	2130	nd	nd	nd	nd	nd	14.2	65.3	nd	nd
02/13/00	2320	nd	nd	nd	nd	nd	nd	252	nd	nd
02/14/00	030	nd	nd	nd	nd	nd	nd	71.4	nd	nd
02/14/00	130	nd	nd	nd	nd	nd	nd	93.2	nd	nd
02/14/00	230	nd	nd	nd	10.9	nd	6.3	61.7	nd	nd
02/14/00	650	nd	nd	nd	nd	nd	13.9	18.9	nd	nd
02/14/00	1100	nd	15.8	nd	nd	nd	nd	12.4	nd	nd
02/14/00	1500	nd	nd	nd	nd	nd	nd	nd	nd	nd
02/15/00	1145	nd	nd	nd	nd	nd	nd	nd	nd	nd
02/16/00	1200	nd	nd	nd	nd	nd	nd	13.3	nd	nd
02/17/00	615	nd	nd	nd	nd	nd	nd	14.3	nd	nd
02/17/00	1830	nd	nd	nd	nd	nd	6.0	nd	nd	nd
02/18/00	1300	nd	nd	nd	nd	nd	nd	nd	nd	nd
02/19/00	1000	nd	nd	nd	nd	nd	nd	14.4	nd	nd

Table 3. Pesticide concentrations in water samples collected at Orestimba Creek at River Road near Crows Landing, California, 2000–2001—*Continued*

Date (mm/dd/yy)	Time	Atrazine	Butylate	Carbaryl	Chlorpyrifos	Cycloate	Dacthal	Diazinon	Diethatyl-ethyl	Eptam
					Sampling year 2001					
01/19/01	1230	8.6	nd	nd	nd	nd	nd	9.9	nd	nd
01/25/01	1445	nd	nd	nd	nd	nd	196	18.4	nd	nd
01/25/01	1700	17.7	nd	nd	nd	nd	nd	11.9	nd	nd
01/25/01	1800	nd	nd	nd	nd	nd	8.5	nd	31.9	nd
01/25/01	1915	4.7	nd	nd	nd	nd	nd	7.8	nd	nd
01/25/01	2000	(3.3)	nd	nd	nd	nd	45.4	9.0	nd	nd
01/25/01	2100	nd	nd	nd	nd	nd	nd	11.0	nd	nd
01/25/01	2200	17.3	nd	nd	nd	nd	122	23.0	nd	nd
01/25/01	2300	(3.1)	nd	nd	nd	nd	82.3	8.3	nd	nd
01/25/01	2359	10.3	nd	nd	nd	nd	39.0	9.0	nd	nd
01/26/01	100	13.2	nd	22.6	nd	nd	38.9	12.8	nd	nd
01/26/01	200	nd	nd	19.2	nd	nd	45.0	7.8	nd	nd
01/26/01	300	18.4	nd	nd	nd	nd	15.7	15.7	nd	nd
01/26/01	400	10.3	nd	nd	nd	nd	22.6	18.7	nd	8.6
01/26/01	500	13.4	nd	nd	nd	nd	19.0	11.7	nd	nd
01/26/01	700	13.5	nd	nd	nd	nd	11.3	15.2	nd	nd
01/26/01	900	10.2	nd	nd	nd	nd	10.5	12.8	nd	nd
01/26/01	1845	9.4	nd	nd	nd	15.0	7.5	16.4	nd	nd
01/27/01	1830	10.8	nd	nd	nd	nd	nd	7.4	nd	nd
01/28/01	1520	18.1	nd	nd	nd	nd	nd	11.4	nd	nd
01/29/01	1430	nd	nd	nd	nd	nd	8.9	9.8	nd	nd
01/30/01	1530	10.9	nd	nd	nd	nd	nd	7.8	nd	nd
01/31/01	1051	10.0	nd	nd	nd	nd	8.3	18.4	nd	nd
02/01/01	1200	8.5	nd	nd	63.7	nd	8.4	49.6	nd	nd
02/05/01	1200	13.3	nd	nd	nd	nd	128	18.0	nd	nd

Table 3. Pesticide concentrations in water samples collected at Orestimba Creek at River Road near Crows Landing, California, 2000–2001—*Continued*

Date (mm/dd/yy)	Time	Ethal-fluralin	Hexa-zinone	Methi-dathion	Meto-lachlor	Molinate	Pendi-methalin	Oxy-fluorfen	Piperonyl butoxide	Simazine	Trifluralin
Sampling year 2000											
01/30/00	1425	nd	—	46.8	6.2	nd	nd	—	—	588	14.8
01/30/00	1625	nd	—	43.5	104	nd	nd	—	—	963	29.0
02/11/00	2335	nd	—	nd	14.5	nd	33.8	—	—	117	32.0
02/12/00	135	20.9	—	9.4	226	nd	30.0	—	—	981	38.9
02/12/00	300	nd	—	(1.6)	62.2	nd	20.0	—	—	104	18.8
02/12/00	335	nd	—	nd	41.3	nd	(10.5)	—	—	366	23.2
02/12/00	630	nd	—	9.4	44.3	nd	30.1	—	—	196	23.2
02/12/00	840	nd	—	9.9	52.0	nd	28.7	—	—	362	27.8
02/12/00	1340	nd	—	nd	22.8	nd	40.4	—	—	283	24.6
02/13/00	2055	nd	—	92.3	9.8	nd	22.3	—	—	182	23.1
02/13/00	2130	nd	—	95.2	38.0	nd	40.6	—	—	191	27.0
02/13/00	2320	nd	—	25.2	10.4	nd	nd	—	—	70.0	30.3
02/14/00	030	nd	—	61.0	35.3	nd	nd	—	—	83.4	41.4
02/14/00	130	nd	—	31.8	nd	nd	nd	—	—	nd	25.5
02/14/00	230	nd	—	30.0	12.9	nd	22.3	—	—	58.3	17.1
02/14/00	650	nd	—	nd	nd	nd	nd	—	—	31.7	19.3
02/14/00	1100	nd	—	nd	nd	nd	nd	—	—	nd	21.8
02/14/00	1500	nd	—	nd	nd	nd	nd	—	—	33.9	6.1
02/15/00	1145	nd	—	nd	11.5	nd	nd	—	—	nd	11.3
02/16/00	1200	nd	—	nd	nd	nd	nd	—	—	57.0	12.5
02/17/00	615	nd	—	nd	nd	nd	nd	—	—	30.7	13.3
02/17/00	1830	nd	—	nd	8.4	nd	14.9	—	—	nd	13.5
02/18/00	1300	nd	—	nd	nd	nd	nd	—	—	nd	21.7
02/19/00	1000	nd	—	nd	nd	nd	nd	—	—	21.3	13.0

Table 3. Pesticide concentrations in water samples collected at Orestimba Creek at River Road near Crows Landing, California, 2000–2001—*Continued*

Date (mm/dd/yy)	Time	Ethal-fluralin	Hexa-zinone	Methi-dathion	Meto-lachlor	Molinate	Pendi-methalin	Oxy-fluorfen	Piperonyl butoxide	Simazine	Trifluralin
Sampling year 2001											
01/19/01	1230	nd	43.6	nd	9.6	nd	8.8	40.1	nd	62.5	25.1
01/25/01	1445	nd	47.5	nd	31.5	nd	27.8	49.2	nd	74.1	24.4
01/25/01	1700	nd	45.1	nd	16.1	nd	25.5	38.3	nd	54.4	16.1
01/25/01	1800	nd	56.2	nd	23.1	nd	38.9	60.9	24.7	54.4	36.8
01/25/01	1915	nd	55.9	nd	10.2	nd	27.2	46.3	nd	45.2	27.6
01/25/01	2000	nd	47.8	nd	34.3	nd	30.3	42.2	nd	58.2	17.4
01/25/01	2100	nd	49.8	nd	12.1	nd	25.5	44.8	nd	41.0	24.1
01/25/01	2200	nd	38.3	nd	23.0	nd	26.0	39.3	nd	67.6	16.0
01/25/01	2300	nd	43.0	nd	16.3	nd	27.8	37.2	nd	116	22.3
01/25/01	2359	nd	35.1	nd	6.7	nd	22.5	28.6	11.6	129	9.7
01/26/01	100	nd	61.4	nd	20.7	nd	24.1	49.7	nd	242	19.1
01/26/01	200	nd	72.0	nd	54.6	nd	61.6	114	nd	315	18.4
01/26/01	300	nd	59.4	nd	29.1	nd	41.1	97.2	nd	337	17.0
01/26/01	400	nd	39.5	nd	21.5	12.3	27.1	52.4	nd	330	19.9
01/26/01	500	nd	35.3	nd	19.0	nd	24.6	51.7	nd	301	19.4
01/26/01	700	nd	41.8	nd	11.9	nd	31.3	64.2	8.9	236	14.6
01/26/01	900	nd	38.6	nd	15.2	nd	22.4	40.7	nd	145	17.4
01/26/01	1845	nd	39.0	nd	21.2	nd	20.5	168	nd	75.8	17.7
01/27/01	1830	nd	40.1	nd	6.2	nd	nd	87.6	13.1	1,611	12.1
01/28/01	1520	nd	40.6	nd	16.3	nd	111	78.9	nd	321	17.0
01/29/01	1430	nd	34.7	nd	16.6	nd	31.5	40.9	nd	60.5	18.6
01/30/01	1530	nd	41.7	nd	4.9	nd	26.7	33.5	nd	62.4	8.3
01/31/01	1051	nd	53.4	nd	14.8	nd	33.8	30.5	5.2	50.3	10.3
02/01/01	1200	nd	29.0	nd	14.3	nd	33.0	30.2	nd	48.1	10.6
02/05/01	1200	nd	26.0	nd	25.1	nd	28.8	33.8	nd	90.2	12.7

Table 4. Pesticide concentrations in water samples collected at San Joaquin River near Vernalis, California, 2000–2001

[Values are reported as nanograms per liter. Water samples were analyzed for the following pesticides that were not detected at this site: alachlor, azinphos-methyl, butylate, carbofuran, cyanazine, cycloate, eptam, fonofos, malathion, methylparathion, molinate, pebulate, sulfotep, and thiobencarb. nd, nondetection; —, not analyzed; ( ), concentration below detection limit]

Date (mm/dd/yy)	Time	Atrazine	Carbaryl	Chlor-pyrifos	Dacthal	Diazinon	Diethatyl-ethyl	Ethal-fluralin	Hex-azinone	Methi-dathion	Meto-lachlor
					Sampling year 2000						
01/24/00	1500	nd	nd	nd	nd	7.6	nd	nd	—	44.8	(2.1)
01/25/00	010	nd	nd	nd	nd	9.3	nd	nd	—	nd	nd
01/25/00	1100	nd	nd	nd	nd	11.5	nd	nd	—	51.4	(3.6)
01/25/00	2000	nd	nd	nd	nd	26.8	nd	nd	—	nd	19.3
01/26/00	730	nd	nd	nd	nd	14.8	nd	nd	—	nd	4.6
01/27/00	820	nd	nd	nd	nd	nd	nd	nd	—	nd	nd
01/27/00	1600	nd	nd	nd	nd	nd	nd	nd	—	nd	nd
02/11/00	2200	10.2	nd	nd	nd	26	nd	nd	—	(0.3)	15.6
02/12/00	1230	11.0	nd	nd	nd	21.8	nd	nd	—	(0.6)	15.1
02/12/00	2100	10.0	nd	nd	nd	31.2	nd	nd	—	nd	6.3
02/13/00	530	13.1	nd	nd	nd	77.1	nd	nd	—	(1.1)	35.3
02/13/00	2330	8.8	nd	nd	nd	40.6	nd	nd	—	(3.9)	18.6
02/14/00	650	11.5	nd	nd	nd	40.7	nd	nd	—	(0.9)	26.2
02/14/00	2000	nd	nd	nd	nd	35.6	nd	nd	—	33.2	21.7
02/15/00	900	nd	nd	12.3	nd	22.5	nd	nd	—	nd	13.2
02/15/00	1000	nd	nd	nd	nd	26.4	nd	nd	—	nd	nd
02/15/00	1830	nd	nd	18.0	nd	17.1	nd	nd	—	nd	18.7
02/16/00	830	nd	nd	nd	nd	13.5	nd	nd	—	nd	4.2
02/16/00	1600	nd	nd	nd	nd	17.9	nd	(0.8)	—	nd	nd
02/16/00	1945	nd	nd	nd	nd	nd	nd	nd	—	nd	nd
02/17/00	930	nd	nd	nd	nd	23.4	nd	nd	—	nd	nd
02/17/00	1930	nd	nd	nd	nd	16.2	nd	nd	—	nd	nd
02/18/00	1005	nd	nd	nd	nd	13.4	nd	nd	—	nd	nd
02/18/00	1930	11.4	nd	nd	nd	nd	nd	nd	—	nd	nd
02/19/00	830	nd	nd	nd	nd	12.6	nd	nd	—	nd	15.7
02/23/00	1200	12.1	nd	nd	nd	nd	nd	nd	—	nd	nd
02/23/00	1200	nd	nd	nd	nd	10.7	nd	nd	—	nd	(3.5)
					Sampling year 2001						
01/19/01	1330	(1.3)	nd	16.3	nd	6.5	nd	nd	30.2	nd	nd
01/26/01	1345	16.0	nd	18.2	10.4	39.3	nd	nd	32.5	33.0	22.3
01/27/01	845	10.7	31.6	nd	nd	133	nd	nd	27.9	17.6	nd
01/27/01	1710	nd	27.5	nd	nd	128	32.0	nd	55.1	29.0	25.6
01/28/01	1030	19.3	nd	nd	nd	134	nd	nd	37.8	nd	19.1
01/28/01	1650	8.6	nd	14.6	nd	154	nd	nd	34.4	26.0	16.8
01/29/01	915	nd	nd	13.4	nd	126	nd	nd	32.5	nd	12.3
01/29/01	930	16.0	nd	nd	nd	137	nd	nd	39.2	nd	18.9
01/29/01	2020	7.8	nd	13.6	nd	113	nd	nd	44.7	nd	16.2
01/30/01	1800	nd	nd	nd	nd	103	nd	nd	106	nd	19.4
01/31/01	800	nd	nd	nd	nd	52.9	nd	nd	105	nd	6.1
02/01/01	1100	nd	8.3	8.2	nd	33.3	nd	nd	47.3	nd	11.1
02/04/01	1200	nd	20.9	nd	nd	22.4	nd	nd	28.7	nd	18.6

Table 4. Pesticide concentrations in water samples collected at San Joaquin River near Vernalis, California, 2000–2001—*Continued*

Date (mm/dd/yy)	Time	Napropamide	Pendimethalin	Phosmet	Oxyfluorfen	Piperonyl butoxide	Simazine	Trifluralin
				Sampling year 2000				
01/24/00	1500	nd	35.1	nd	—	—	95.0	15.6
01/25/00	010	nd	35.3	nd	—	—	80.8	15.6
01/25/00	1100	nd	42.9	53.9	—	—	123	17.3
01/25/00	2000	nd	37.9	nd	—	—	244	nd
01/26/00	730	nd	36.2	nd	—	—	149	nd
01/27/00	820	nd	37.2	nd	—	—	136	nd
01/27/00	1600	nd	40.3	nd	—	—	99.6	nd
02/11/00	2200	nd	16.8	nd	—	—	45.2	15.8
02/12/00	1230	nd	13.3	nd	—	—	35.4	15.8
02/12/00	2100	nd	25.7	nd	—	—	206	14.7
02/13/00	530	nd	28.6	nd	—	—	106	21.3
02/13/00	2330	nd	18.8	nd	—	—	448	16.6
02/14/00	650	nd	22.6	nd	—	—	469	20.6
02/14/00	2000	28.4	nd	nd	—	—	471	nd
02/15/00	900	38.9	17.5	nd	—	—	461	13.1
02/15/00	1000	37.3	20.7	nd	—	—	470	13.7
02/15/00	1830	nd	36.0	nd	—	—	487	6.4
02/16/00	830	45.7	nd	nd	—	—	435	nd
02/16/00	1600	12.7	17.9	nd	—	—	331	14.5
02/16/00	1945	nd	43.2	nd	—	—	304	6.4
02/17/00	930	nd	19.6	nd	—	—	166	10.8
02/17/00	1930	nd	18.4	nd	—	—	133	11.5
02/18/00	1005	nd	nd	nd	—	—	113	9.8
02/18/00	1930	nd	23.6	nd	—	—	157	13.7
02/19/00	830	nd	nd	nd	—	—	124	6.7
02/23/00	1200	nd	23.5	nd	—	—	122	14.4
02/23/00	1200	nd	nd	nd	—	—	63.6	nd
				Sampling year 2001				
01/19/01	1330	nd	24.1	nd	nd	19.6	51.1	21.4
01/26/01	1345	nd	27.3	nd	25.0	19.6	111	18.3
01/27/01	845	nd	39.0	nd	nd	15.1	179	8.1
01/27/01	1710	nd	72.7	nd	57.7	28.2	178	35.4
01/28/01	1030	90.7	64.2	nd	nd	nd	376	nd
01/28/01	1650	79.8	39.8	nd	nd	nd	372	16.3
01/29/01	915	62.7	35.0	nd	nd	4.5	694	10.5
01/29/01	930	67.7	40.7	nd	nd	nd	731	nd
01/29/01	2020	34.0	32.9	nd	nd	12.6	664	16.0
01/30/01	1800	nd	26.3	nd	nd	16.6	468	19.7
01/31/01	800	nd	25.7	nd	nd	14.0	453	8.6
02/01/01	1100	nd	22.3	nd	nd	10.5	211	11.3
02/04/01	1200	nd	23.5	nd	nd	3.9	79.0	9.0

Table 5. Method detection limits for pesticides analyzed in 2000 and 2001

[—, not analyzed]

Pesticide	2000 Method detection limit, in nanogram per liter	2001 Method detection limit, in nanogram per liter
Alachlor[1]	3.8	2.1
Atrazine	4.3	4.2
Azinphos-methyl[1]	—	11.1
Butylate	4.5	1.8
Carbaryl	4.6	4.2
Carbofuran	5.5	3.3
Chlorpyrifos	1.5	4.2
Cyanazine1	—	3.0
Cycloate	2.2	1.5
Dacthal	1.5	1.2
Diazinon	2.0	3.6
Diethatyl-ethyl	2.2	3.6
Eptam	5.7	4.5
Ethalfluralin	5.0	2.4
Fonofos[1]	3.5	2.4
Hexazinone	—	5.7
Malathion[1]	3.1	2.1
Methidathion	5.5	5.4
Methylparathion[1]	6.9	4.2
Metolachlor	4.0	3.3
Molinate	4.0	2.7
Napropamide	10.9	7.2
Oxyfluorfen	—	4.2
Pebulate[1]	3.4	0.6
Pendimethalin	12.4	2.4
Phosmet	5.9	4.2
Piperonyl butoxide	—	3.3
Simazine	5.2	6.9
Sulfotep[1]	2.0	1.2
Thiobencarb[1]	3.4	3.9
Trifluralin	3.1	3.0

[1]Pesticide not detected in any samples in either year.

Significant figures were estimated by the rounding method as described in American Society for Testing and Materials (1993).

REFERENCES CITED

American Society of Testing and Materials, 1993, Annual book of ASTM standards, Committee E-11 on Quality and Statistics, ASTME29-93a: Standard practice for using significant digits in test data to determine conformance with specifications: p. 18–21.

California Department of Food and Agriculture, 2001, California agricultural resource directory, 2001: Sacramento, Calif., California Department of Food and Agriculture, 180 p.

Dubrovsky, N.M., Kratzer, C.R., Brown, L.R., Gronberg, J.M., and Burow, K.R., 1998, Water quality in the San Joaquin–Tulare basins, California, 1992–95: U.S. Geological Survey Circular 1159, 38 p.

Foe, C.G., and Connor, V., 1991, San Joaquin watershed bioassay results, 1988–90: Central Valley Regional Water Quality Control Board, Staff Report, Sacramento, Calif., 79 p.

Kratzer, C.R., 1997, Transport of diazinon in the San Joaquin River Basin, California: U.S. Geological Survey Open File Report 97-411, 22 p.

Kuivila, K.M., and Foe, C.G., 1995, Concentrations, transport, and biological effects of dormant spray pesticides in the San Francisco Estuary, California: Journal of Environmental Toxicology and Chemistry, v. 14, no. 7, p. 1141–1150.

Panshin, S.Y., Dubrovsky, N.M., Gronberg, J.M., and Domagalski, J.L., 1998, Occurrence and distribution of dissolved pesticides in the San Joaquin River Basin, California: U.S. Geological Survey Water-Resources Investigations Report 98-4032, 88 p.