APPENDIX 2-1 Water Quality in the San Joaquin-Tulare Basin

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Eastern San Joaquin Region
2015 IRWM Implementation Grant Application

Water Quality in the San Joaquin-Tulare Basins

California, 1992–95

U.S. Department of the Interior
U.S. Geological Survey

Circular 1159

A COORDINATED EFFORT

Coordination among agencies and organizations is an integral part of the NAWQA Program. We thank the following agencies and organizations who directly participated in the San Joaquin–Tulare Basins program.

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Front cover: Yosemite National Park.
(Photograph by Sylvia V. Stork, U.S. Geological Survey)
Back cover: Ground-water sampling in vineyards in eastern Fresno County, and Ecological survey at a site on the San Joaquin River.
(Photographs by Neil M. Dubrovsky, U.S. Geological Survey)

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Information on the NAWQA Program is also available on the Internet via the World Wide Web. You may connect to the NAWQA Home Page using the Universal Resources Locator (URL):
http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html

The San Joaquin–Tulare Basins Study Unit's Home Page is at URL:
http://water.wr.usgs.gov/sanj_nawqa/

Water Quality in the San Joaquin–Tulare Basins, California, 1992–95

By Neil M. Dubrovsky, Charles R. Kratzer, Larry R. Brown, JoAnn M. Gronberg, *and* Karen R. Burow

U.S. GEOLOGICAL SURVEY CIRCULAR 1159

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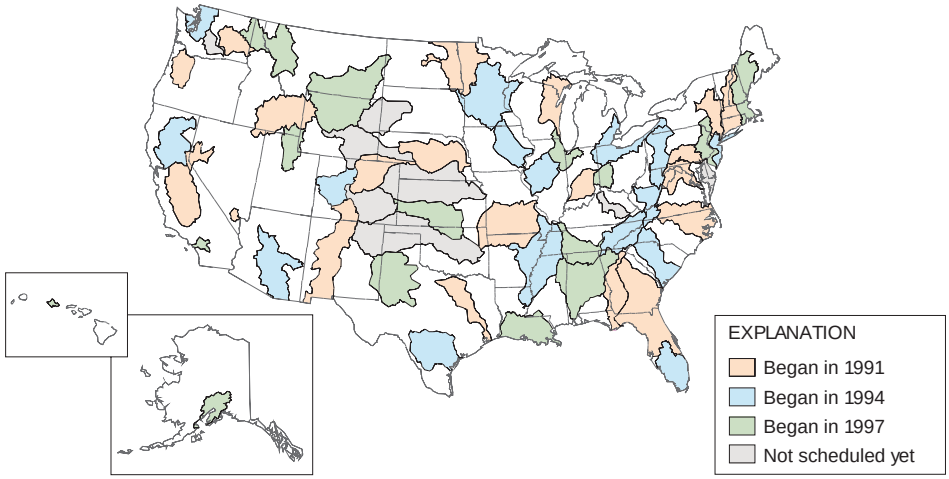


Knowledge of the quality of the Nation's streams and aquifers is important because of the implications to human and aquatic health and because of the significant costs associated with decisions involving land and water management, conservation, and regulation. In 1991, the U.S. Congress appropriated funds for the U.S. Geological Survey (USGS) to begin the National Water-Quality Assessment (NAWQA) Program to help meet the continuing need for sound, scientific information on the areal extent of the water-quality problems, how these problems are changing with time, and an understanding of the effects of human actions and natural factors on water quality conditions.

The NAWQA Program is assessing the water-quality conditions of more than 50 of the Nation's largest river basins and aquifers, known as Study Units. Collectively, these Study Units cover about one-half of the United States and include sources of drinking water used by about 70 percent of the U.S. population. Comprehensive assessments of about one-third of the Study Units are ongoing at a given time. Each Study Unit is scheduled to be revisited every decade to evaluate changes in water-quality conditions. NAWQA assessments rely heavily on existing information collected by the USGS and many other agencies as well as the use of nationally consistent study designs and methods of sampling and analysis. Such consistency simultaneously provides information about the status and trends in water-quality conditions in a particular stream or aquifer and, more importantly, provides the basis to make comparisons among watersheds and improve our understanding of the factors that affect water-quality conditions regionally and nationally.

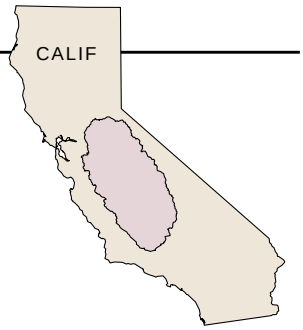
This report is intended to summarize major findings that emerged between 1992 and 1995 from the water-quality assessment of the San Joaquin–Tulare Basins Study Unit and to relate these findings to water-quality issues of regional and national concern. The information is primarily intended for those who are involved in water-resource management. Indeed, this report addresses many of the concerns raised by regulators, water-utility managers, industry representatives, and other scientists, engineers, public officials, and members of stakeholder groups who provided advice and input to the USGS during this NAWQA Study-Unit investigation. Yet, the information contained here may also interest those who simply wish to know more about the quality of water in the rivers and aquifers in the area where they live.

Robert M. Hirsch

Robert M. Hirsch, Chief Hydrologist

"The scientific and technical information contained in this report provides valuable assistance in California's efforts to better understand and implement programs to address water resource issues—not only in the San Joaquin–Tulare Basins, but throughout the state."

Walt Pettit, Executive Director, California State Water Resources Control Board



This report summarizes the major findings of the National Water-Quality Assessment (NAWQA) for the San Joaquin–Tulare Basins, California. The brief statements of the major findings that follow are expanded on later in this report (p. 6–19). Comparisons of data within this Study Unit with data from all 20 Study Units nationwide are given in descriptive (p. 20–23) and tabular (p. 26–31) formats. Additional information on the methods, approaches, and findings of all the investigations of the San Joaquin–Tulare Basins NAWQA studies is available in the technical reports listed on pages 32–33. Though this report is an integral part of a national study, it also is intended to serve as a stand-alone resource for anyone interested in water quality in California.

Toxicity to Aquatic Organisms in Streams Attributed to Pesticides

The California Water Resources Control Board has set a goal of zero toxicity in surface water in the San Joaquin River system. This goal is based on concerns for maintenance of anadromous fish, endangered fish in the Sacramento–San Joaquin Delta, and human health. Toxicity may result from several causes, but generally has been attributed to pesticides from agricultural nonpoint sources. High concentrations of organophosphate insecticides, resulting from application to some orchards during the winter, are of particular concern. (p. 6–9)

A wide variety of pesticides occur in the San Joaquin River and its tributaries, some at concentrations high enough to adversely impact aquatic life.

- Forty-nine pesticides were detected in the San Joaquin River and three subbasins, 22 of which were detected in more than 20 percent of the samples. Available drinking-water standards were not exceeded, but the concentrations of seven pesticides exceeded the criteria for the protection of aquatic life.
- Pesticide occurrence is related to the timing and spatial distribution of pesticide application; the most frequent occurrence and highest concentrations generally coincide with the time of heaviest agricultural application.
- Crop type and basin characteristics affect spatial and seasonal variability of pesticide occurrence.
- The main source of organophosphate insecticides is the application to dormant orchards. Concentrations of organophosphate insecticides in runoff are high, and highly variable, during winter storms. Peak diazinon concentrations in Orestimba Creek, in the Merced and the Tuolumne Rivers, and in the main stem of the San Joaquin River frequently exceeded levels that can be acutely toxic to some aquatic life.
- Diazinon and other pesticides were also found to be transported to the Tuolumne River in stormwater runoff from the Modesto urban area.

Potential for Adverse Effects on Biota from Pesticides in Bed Sediment and Biota

Long-banned organochlorine insecticides, such as DDT, are bound to soil particles in areas of past application. The soils and associated bound pesticides are transported to streams by soil erosion during natural or irrigation-related runoff. Once in the stream, organochlorine insecticides are taken up by organisms and bioaccumulated through the food chain. These compounds have been shown to be harmful to wildlife and humans that consume them. (p. 10–11)

Long-banned organochlorine insecticides continue to be transported to streams by soil erosion of contaminated agricultural fields, resulting in contamination of suspended sediment, bed sediment, and aquatic organisms.

- Concentrations of organochlorine insecticides, such as DDT, toxaphene, and chlordane, in tissues of clams and fish from the San Joaquin River and its western tributaries, were high relative to national values obtained in the 1970s and 1980s.
- Concentrations of DDT compounds in fine-grained bed sediments and tissue samples are correlated, suggesting that bioaccumulation is taking place.
- Most whole-water concentrations of *p,p´*-DDT, chlordane, dieldrin, and toxaphene exceeded chronic criteria for the protection of freshwater aquatic life.
- Runoff from winter storms will continue to deliver a substantial load of sediment-bound organochlorine insecticides to the San Joaquin River, even if irrigation-induced soil erosion is reduced.

Nutrient Concentrations in the San Joaquin River Generally Support the Beneficial Uses

Designated beneficial uses for the San Joaquin River include drinking water and the aquatic ecosystem. Nitrate and ammonia criteria have been set

Some nitrate and ammonia concentrations exceed criteria in some small tributaries, but generally do not limit beneficial uses in the main stem of the San Joaquin River.

- Mud and Salt Sloughs account for only about 10 percent of the streamflow but contribute nearly half the nitrate load in the San Joaquin River.

by USEPA to protect these beneficial uses. The San Joaquin River Basin has many sources of nitrate and ammonia: fertilizer and manure, subsurface agricultural drains, dairies, and wastewater-treatment plants. (p. 12–13)

- Nitrate concentrations in the San Joaquin River have been increasing over the last 40 years, but concentrations are still well below the drinking-water standard.
- Ammonia criteria were frequently exceeded in Turlock Irrigation District lateral 5, and occasionally in Orestimba Creek and Spanish Grant Drain. None of the samples collected in the main stem of the San Joaquin River exceeded criteria during 1993–95.

Habitat Disruption and Water Chemistry Have Adversely Affected Native Fish Populations

Development of water resources in the San Joaquin River drainage, including the Sacramento-San Joaquin Delta, has been accompanied by large-scale changes in the aquatic ecosystems, including fish populations. Anadromous salmon have declined, along with other migratory and resident native fish species. Though there are likely multiple reasons for declines in native fish species, the roles of water chemistry and habitat degradation have never been addressed on a basinwide basis. (p. 14–15)

Fish communities in the San Joaquin River and its tributaries change in response to water chemistry and habitat quality in a pattern suggesting that human activities, including agriculture, are important factors in controlling the distribution and abundance of fish species. Fish communities in the lower San Joaquin River were highly degraded compared with other NAWQA Study Units, as was stream habitat at some sites.

- Introduced fish species outnumber native fish species by almost 2 to 1.
- In the lower San Joaquin River drainage, four groups of sites can be defined on the basis of fish communities. Native species were most common near the foothill dams and were gradually replaced by different groups of introduced species in downstream areas where land use is dominated by agriculture and other human activities.
- The Stanislaus River appeared to provide the best habitat for native species of the three major tributaries studied, possibly because of the way flow is managed in the Stanislaus River compared with that of the Tuolumne and Merced Rivers.
- Fish communities provide a useful assessment of overall stream health of San Joaquin Valley streams. Though the analysis cannot separate the individual effects of water chemistry (including toxicity) and habitat quality, both appear to be important.

Drinking-Water Supplies From Ground Water Have Been Degraded by Fertilizers and Pesticides

Ground water is the primary source of drinking water for the majority of the population in the eastern San Joaquin Valley. Millions of pounds of pesticides and fertilizer have been used on agricultural land in the valley. Prior data have shown ground-water contamination by agricultural nonpoint sources. (p. 16–19)

Nitrate concentrations in ground water frequently exceeded drinking water standards; however, pesticide concentrations rarely exceeded drinking-water standards, with the notable exception of 1,2,-dibromo-3-chloropropane (DBCP).

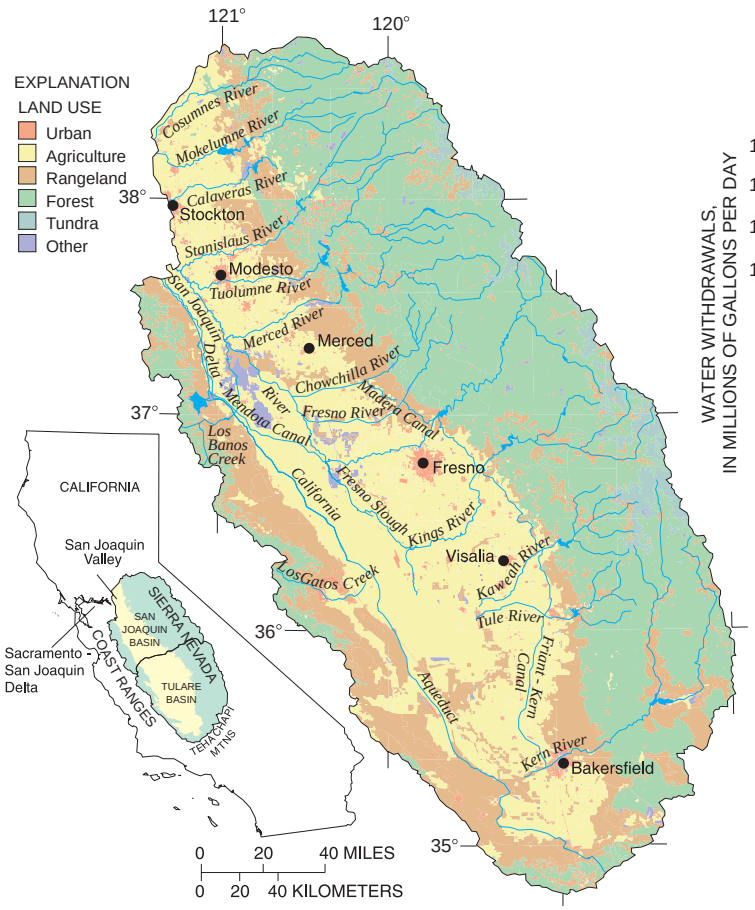
- Nitrate concentrations in ground water in the eastern San Joaquin Valley exceeded the U.S. Environmental Protection Agency (USEPA) drinking-water standard in about one fourth of the domestic water-supply wells sampled.
- Nitrate concentrations in shallow ground water were related to the overlying agricultural land-use setting; concentrations varied among different agricultural land-use settings and were linked to fertilizer application, physical characteristics of the sediment, and biochemical processes in ground water.
- Nitrate concentrations in ground water have increased since the 1950s. From 1950 to 1980, the largest source of nitrate—nitrogen fertilizer—also increased from 114 to 745 million pounds per year.
- Pesticides were detected in about two-thirds of the ground-water samples collected from domestic water supply wells, but concentrations of most pesticides were low—less than 0.1 microgram per liter (µg/L).
- DBCP concentrations exceed the USEPA drinking-water standard of 0.2 µg/L in 20 percent of the domestic water supply wells sampled. Data from monitoring wells show that DBCP concentrations generally decrease with depth and are highly variable near the water table.
- Pesticide concentrations in ground water generally have not increased in the last decade on the basis of a small number of wells sampled (19) during 1986–87 and again in 1995. Direct comparison of the data is difficult because of changes in detection limits.

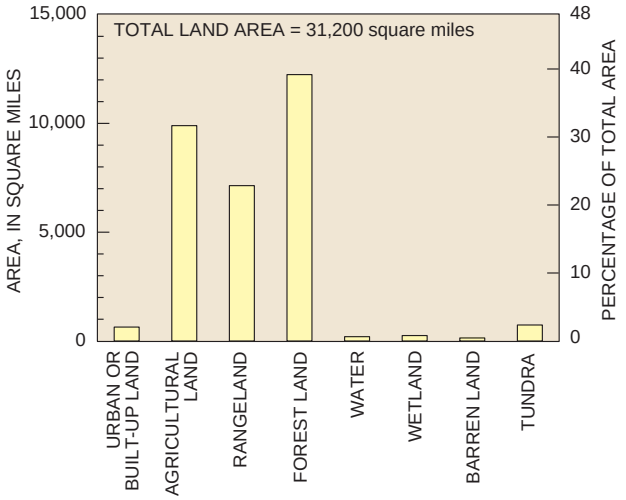
The San Joaquin–Tulare Basins NAWQA Study Unit is located in central California and includes the San Joaquin Valley, the eastern slope of the Coast Ranges, and the western slope of the Sierra Nevada.

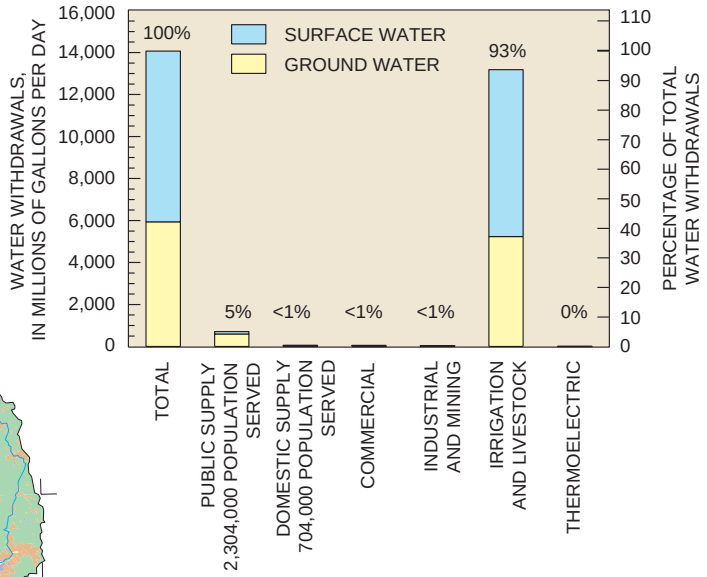
The Sierra Nevada are predominantly forested land, and the Coast Ranges and the foothills of the Sierra Nevada are rangeland. Almost the entire valley floor is used for agricultural land. In 1987, about 10.5 million acres in the San Joaquin Valley was farmland (San Joaquin Valley Drainage Program, 1990, p. 50). Abundant water, combined with the long growing season, results in an exceptionally productive agricultural economy in the San Joaquin Valley. In 1987, approximately 10.2 percent of the total value of agricultural production in the United States came from California, 49 percent of which, or $6.82 billion, was from the San Joaquin Valley.

Thirty-eight percent of the surface water is imported from the Sacramento–San Joaquin Delta through the Delta-Mendota Canal and California Aqueduct (U.S. Bureau of Reclamation, 1990; California Department of Water Resources, 1991). Most of the rest of the surface water is from the Sierra Nevada. Surface water from the Sierra Nevada is of very high quality, but major changes in water quality occur when surface water enters the San Joaquin Valley. These changes are primarily due to the large amount of irrigated agriculture, which affects the quality of both surface and ground water in the valley.

Irrigation return water may reach surface water as direct runoff (tailwater), as water from subsurface drainage systems installed to control the water table, or as ground water discharged through riverbeds. The result can be increased concentrations of dissolved solids, nutrients, pesticides, and, in some areas, trace elements. Irrigation is the largest source of recharge to the regional aquifer, and this ground-water recharge can contain higher concentrations of dissolved solids than natural recharge in the past. This recharge also may contain elevated concentrations of nutrients, pesticide residues, and trace elements.





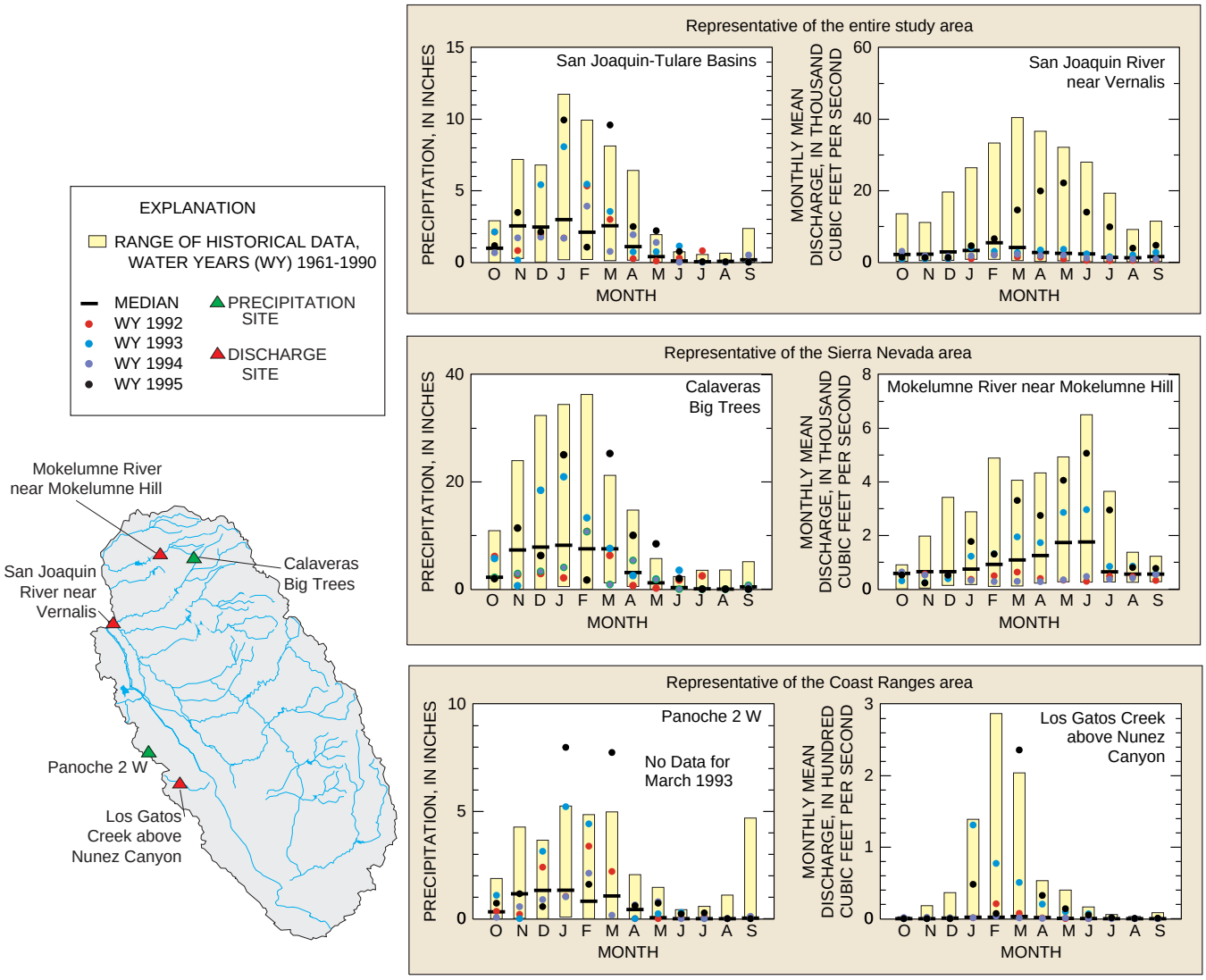


Irrigation of agricultural land on the valley floor is the primary use of water in the San Joaquin–Tulare Basins.

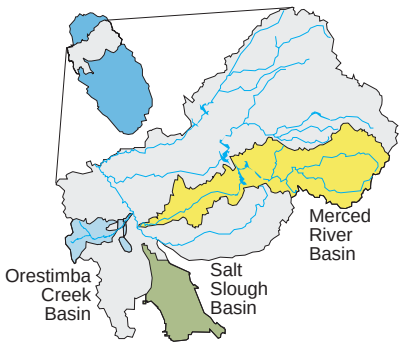
The distribution of precipitation, and consequently runoff, in the San Joaquin–Tulare Basins is highly influenced by topography. Mean annual precipitation on the valley floor ranges from less than 5 inches in the south to 15 inches in the north. Precipitation in the Coast Ranges varies from less than 10 inches (at Panoche 2 W) to more than 20 inches. Average annual precipitation in the Sierra Nevada, mostly in the form of snow, ranges from about 20 inches in the lower foothills to more than 80 inches at some higher elevation sites (Calaveras Big Trees).

Hydrologic conditions during the intensive data collection phase (1992–95 water years [WYs]) of the San Joaquin–Tulare Basins NAWQA were variable. Precipitation in WYs 1993 and 1995 was above the 1961–90 average of 19.4 inches (42 and 70 percent, respectively). The 1992 and 1994 WYs were slightly below average (16 and 26 percent, respectively). Approximately 80 percent of the annual precipitation normally occurs from November to March. The temporal distribution of precipitation during the intensive data collection phase followed this pattern, with slightly greater departure from average during drier years.

Total streamflows at the San Joaquin River near Vernalis site, during WYs 1992–94, were 48 to 78 percent below average, whereas streamflow during WY 1995 was 91 percent above average. Eighty-five percent of the streamflow normally occurs from November to March in the Coast Ranges, reflecting the pattern of precipitation. In the Sierra Nevada, and in the San Joaquin–Tulare Basins as a whole, only 40 to 50 percent of the streamflow occurs from November to March; the greater proportion of the streamflow comes from snowmelt stored in the reservoirs, which is not released until later in the spring. During the intensive data-collection period there was little departure (less than 10 percent) from these temporal patterns, except in 1995 at the San Joaquin River near Vernalis where more of the streamflow occurred during the spring.



Hydrologic conditions during the intensive data-collection phase were highly variable.



Selected subbasins sampled in the San Joaquin River Basin.

Pesticide criteria for the protection of aquatic life were frequently exceeded

Although USEPA drinking-water standards were not exceeded, criteria for the protection of freshwater aquatic life were exceeded in 37 percent of the stream samples (Panshin and others, in press). Concentrations of seven pesticides exceeded criteria for aquatic life; these are the herbicides diuron and trifluralin; and the insecticides azinphos-methyl, carbaryl, chlorpyrifos, diazinon, and malathion. Forty percent of these exceedances are attributed solely to diazinon.

The exceedance of a water-quality criteria indicates a strong probability that aquatic species are being adversely affected. Aquatic life criteria are determined by exposing test organisms to water containing only one pesticide at a time. Most of the samples tested in this study contained mixtures of more than 7, and as many as 22, different pesticides. The toxicity of combinations of pesticides is largely unknown, but there is some potential for additive or interactive effects.

Pesticides were detected in all but one of the 143 surface-water samples collected during calendar year 1993 from four sites—Orestimba Creek, Salt Slough, Merced River, and San Joaquin River near Vernalis. These sites were selected to evaluate how the concentrations of dissolved pesticides vary in contrasting parts of the basin and during different seasons (Panshin and others, in press).

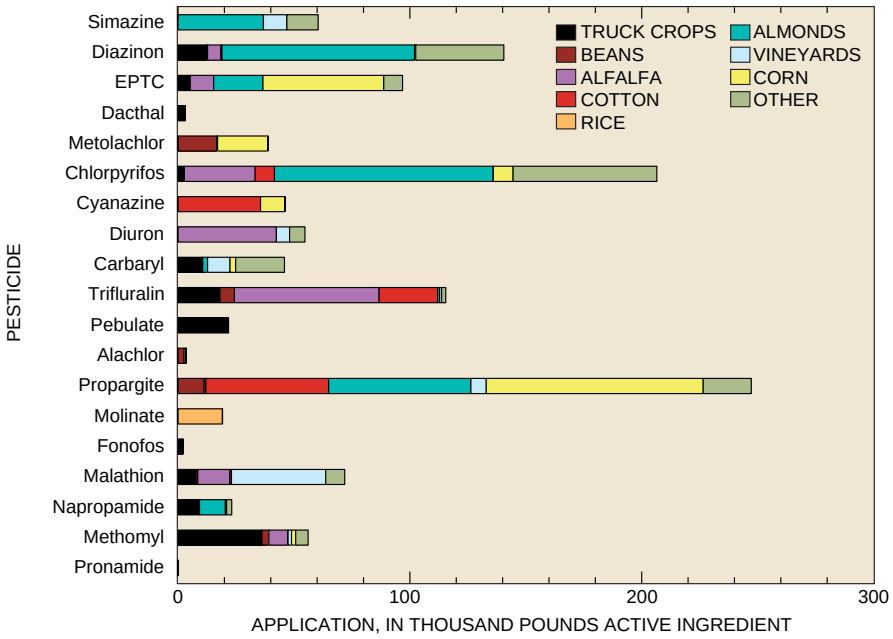
Forty-nine of the 83 pesticides analyzed for were detected. The most commonly occurring ones were the herbicides simazine, dacthal, metolachlor, and EPTC, and the insecticides diazinon and chlorpyrifos. Concentrations of the detected pesticides usually were low, but highly variable: median concentrations of the six most frequently detected pesticides ranged from 0.004 µg/L for dacthal to 0.050 µg/L for simazine, and 10 pesticides had maximum concentrations greater than 1 µg/L. Over half of the pesticides detected have no established aquatic-life criteria, and the potential for these compounds to induce toxicity, endocrine disruption, or impaired immune response is not well known.

Detections of pesticides in surface waters are related to where and when pesticides are applied

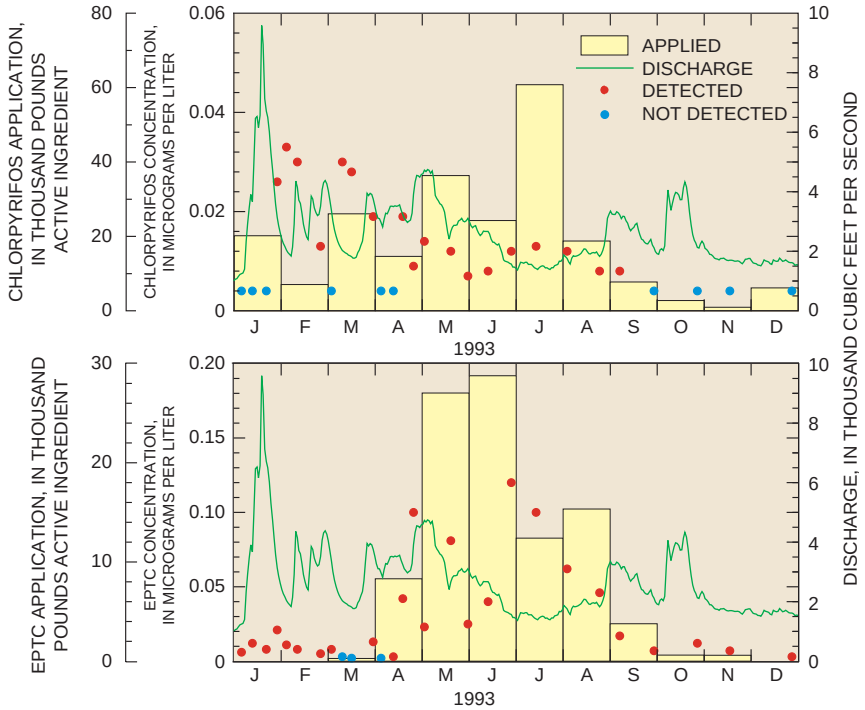
The California Department of Pesticide Regulation maintains detailed information on pesticide application. This information includes type of compound, location, date, amount applied, and target crop for each pesticide application. The vast majority of pesticide application in the Study Unit is for agricultural use.

Seventy percent (38 of 54) of the pesticides with known application were detected. Detection frequency is also related to the amount of pesticide applied; 4 of the 6 most commonly detected pesticides were among the 10 most heavily applied of the pesticides analyzed: chlorpyrifos, diazinon, EPTC, and simazine.

There is often a correspondence between the time a pesticide was applied and when, and at what concentration, it was detected (Panshin and others, in press). The maximum application and occurrence generally coincided for 19 pesticides (for example, EPTC), usually during the summer irrigation season. In contrast, several pesticides (for example, chlorpyrifos) attained their maximum concentration in streams during winter runoff rather than at the time of maximum application. This indicates that, in some cases, winter runoff was more efficient than irrigation return flows at transporting pesticides from the site of application to a stream. During the autumn there is neither rainfall nor irrigation, resulting in relatively few detections.



The diversity of crops and pesticides applied is large in the San Joaquin River Basin (California Department of Pesticide Regulation, 1994).



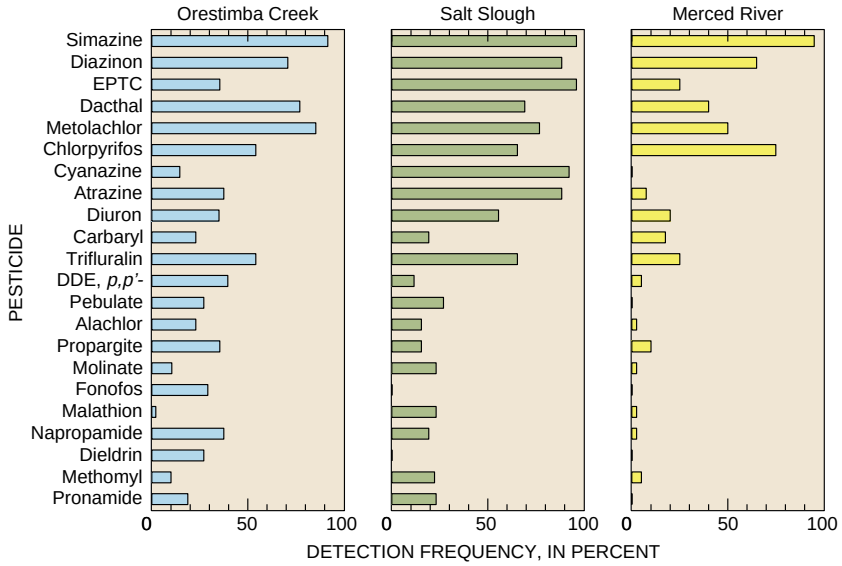
Data for monthly pesticide application in the San Joaquin River Basin and concentration in samples in the San Joaquin River near Vernalis show that the occurrence and application are often related in the summer, whereas the concentration may peak in the winter in spite of heavier application in the summer.

Crop type and basin characteristics affect spatial and seasonal variability of pesticide occurrence

Orestimba Creek is typical of the small western tributaries to the San Joaquin River where streamflow is predominantly agricultural runoff during the summer, but may also include large amounts of runoff from the nonagricultural Coast Ranges during the winter. A greater variety of pesticides were detected here (28 herbicides and 12 insecticides) compared with the other sites. During the winter, high concentrations of some pesticides occur for brief periods because of transport by rainfall runoff (see the following section and Domagalski and others, 1997). During the irrigation season, a large number of pesticides—usually greater than 15—were detected (Panshin and others, in press). Pesticides detected more frequently in Orestimba Creek than at the other sites include DDE, dieldrin, fonofos, napropamide, and propargite. The presence of these pesticides is attributed to past or present application primarily on dry beans and truck crops.

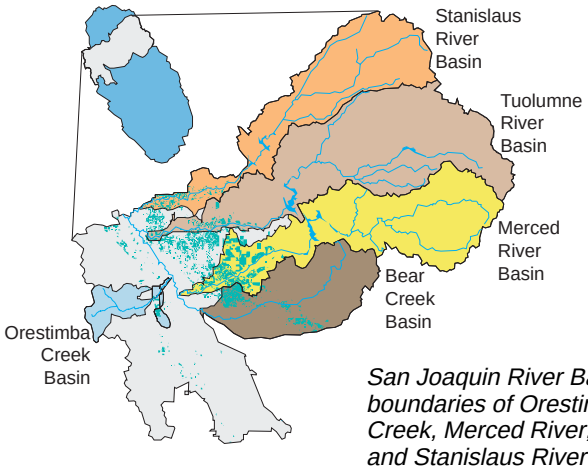
Salt Slough drains a low-lying part of the San Joaquin Valley, which includes large areas of wetlands and cotton; the slough does not have a significant upland area within its basin, and its streamflow is dominated by agricultural drainage much of the year. Twenty-five herbicides and eight insecticides were detected at this site. Pesticides detected more frequently at Salt Slough than at other sites were atrazine, cyanazine, diuron, EPTC, malathion, and molinate. The presence of these pesticides is attri-buted to application primarily on cotton, rice, alfalfa, and truck crops.

The Merced River is one of three tributaries that carry runoff from the Sierra Nevada year round, often as reservoir release, and runoff from agricultural areas during the summer. Although 26 pesticides were detected in this river, the frequency of detection and concentrations were usually much lower than corresponding levels in the other two basins. This relatively low occurrence is due to a combination of factors: the generally coarse-grained soils of the eastern San Joaquin Valley result in little surface runoff during rainfall or irrigation; and pesticides that do reach the Merced River are diluted by the release of the relatively pesticide-free water from a reservoir in the Sierra Nevada foothills.



Some pesticides were detected frequently in samples from all three subbasins, whereas other pesticides were detected in samples from only one or two subbasins.

Almond orchard spraying (photograph by Dave Kim, California Department of Pesticide Regulation).



San Joaquin River Basin showing boundaries of Orestimba Creek, Bear Creek, Merced River, Tuolumne River, and Stanislaus River Basins (almond orchards shown in green).

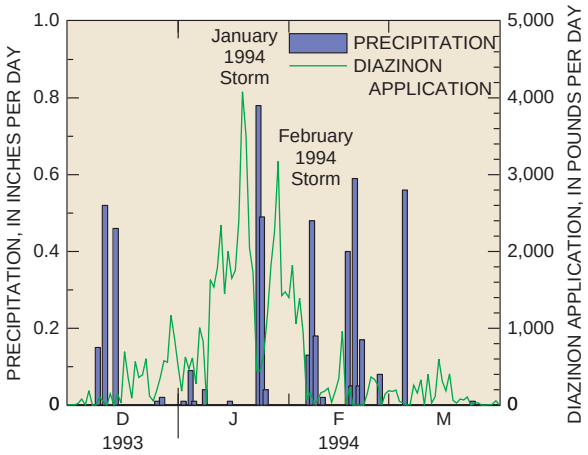
The organophosphate insecticide diazinon is used for many agricultural and urban applications. The main agricultural application of diazinon in the San Joaquin River Basin occurs during the winter to control wood-boring insects in dormant almond orchards. This application period coincides with the rainy season.

Concentrations of diazinon during storm runoff frequently exceeded toxic levels

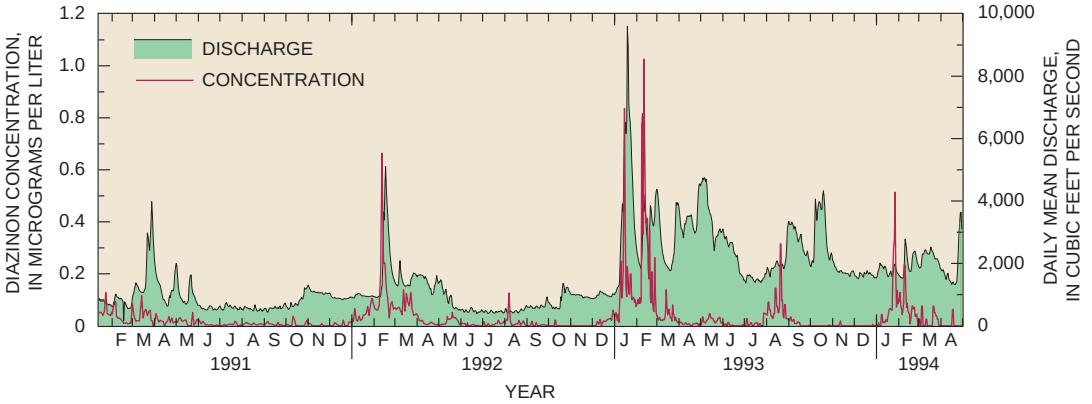
Diazinon concentrations during winter storm runoff in Orestimba Creek, and in the Merced, Tuolumne, and San Joaquin Rivers frequently exceeded 0.35 µg/L, a concentration shown to be acutely toxic to water fleas (Kuivila and Foe, 1995; Domagalski and others, 1997; Kratzer, 1997). Although this level is acutely toxic to water fleas, the effect on other organisms is largely unknown. Concentrations in the Stanislaus River never exceeded 0.35 µg/L. On the basis of daily samples from the San Joaquin River during 1991–94, diazinon concentrations only exceeded 0.35 µg/L during January and February storm runoff (MacCoy and others, 1995).

Transport of diazinon in the San Joaquin River is related to timing of diazinon application and storms

The main factors involved in the transport of diazinon in the San Joaquin River are the timing of diazinon applications and the occurrence of sizable storms during January and February. During 1991–93, 74 percent of diazinon transport in the San Joaquin River occurred during January and February. In 1994, about half of the diazinon application in agricultural areas of the San Joaquin River Basin occurred during two dry periods preceding sampled storms during January and February. The overall amount of diazinon transported in the San Joaquin River during these storms was only about 0.05 percent of the amount applied during the preceding dry periods.

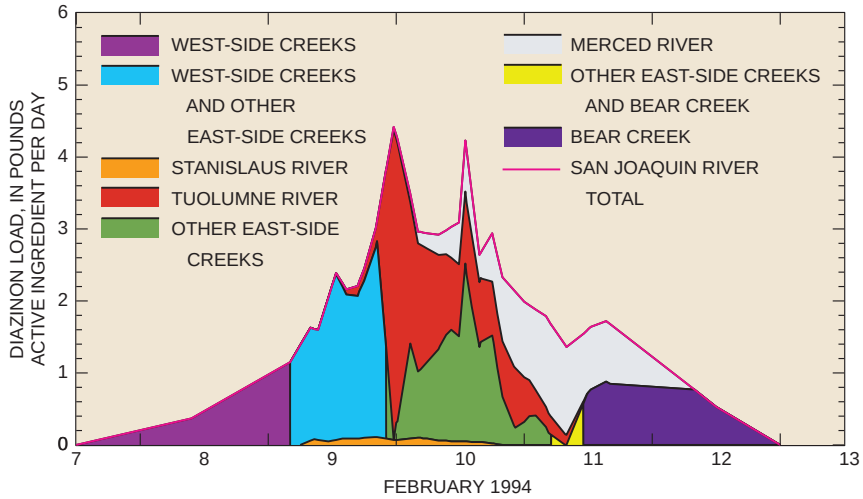


About half of the total agricultural application of diazinon in 1994 occurred during two dry periods preceding storms.



Diazinon concentrations at the San Joaquin River near Vernalis exceeded concentrations toxic to aquatic life (0.35 microgram per liter) only during January and February because of storm runoff.

A dye-tracer study was done during the February 1994 storm to estimate traveltimes in the San Joaquin River system (Kratzer and Biagtan, 1997). On the basis of storm sampling during 1993–94 and estimated traveltimes, ephemeral west-side creeks probably were the main diazinon source early during the storms, whereas the Tuolumne and Merced Rivers and east-side drainages directly to the San Joaquin River were the main sources later (Domagalski and others, 1997; Kratzer, 1997).



Most diazinon in the San Joaquin River comes from west-side creeks, the Tuolumne and Merced Rivers, and direct drainage from the east side.

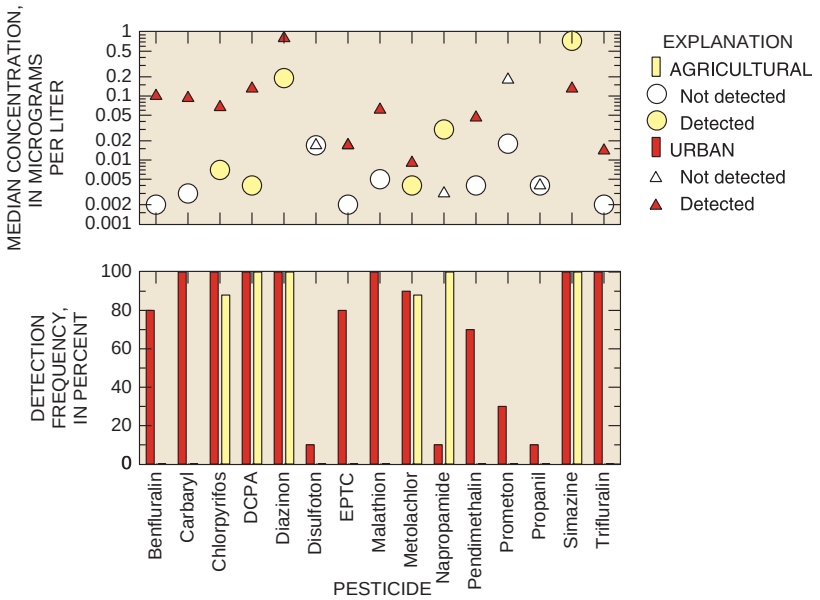
More pesticides were detected in runoff from urban areas than from agricultural areas in the Tuolumne River Basin, but pesticide transport was usually greater in runoff from agricultural areas

The occurrence, concentrations, and transport of dissolved pesticides in storm runoff were compared in the Tuolumne River Basin for two land uses: agricultural areas and the Modesto urban area. Both storms followed the main application period of pesticides on dormant almond orchards. Six pesticides were detected in runoff from agricultural areas, and 15 pesticides were detected in runoff from urban areas. Chlorpyrifos, diazinon, DCPA, metolachlor, and simazine were detected in almost every sample. Median concentrations were higher in runoff from urban areas for all pesticides except napropamide and simazine. The lower occurrence and concentrations in agricultural runoff was partly attributed to dilution by nonstorm base flow in the Tuolumne River and by storm runoff from nonagricultural land (primarily native vegetation) (Kratzer, in press).

Transport of chlorpyrifos, diazinon, metolachlor, napropamide, and simazine was greater from agricultural areas than from urban areas. Transport of DCPA was about the same from agricultural and urban areas. The main source of transport for the other pesticides could not be determined.

In most cases, the occurrence and relative concentrations of pesticides in storm runoff from agricultural and urban areas were related to pesticide applications. Some pesticides detected frequently, and in relatively high concentrations, in the storm drains did not relate to reported use. However, unlike agricultural use, reporting of pesticide use in urban areas is incomplete and only includes use by licensed pest control operators.

Sampling a storm drain during February 1995 storm (photograph by Charles R. Kratzer, U.S. Geological Survey).



More pesticides were detected, and generally in higher concentrations, in storm runoff from urban areas compared with storm runoff from agricultural areas.

Organochlorine insecticides, such as DDT and toxaphene, were used extensively in the San Joaquin Valley to control agricultural pests. The use of such compounds was banned in the 1970s in the United States because of detrimental effects on wildlife, such as the bald eagle and peregrine falcon. These chemicals are persistent in the environment because they degrade slowly and are tightly bound to soil particles. Contaminated soils from agricultural and urban areas containing these compounds are still entering streams because of soil erosion. Once contaminated soil has entered a stream as sediment, it becomes available to a variety of small aquatic organisms, such as insects that obtain food from the water or bed sediment. These organisms then are eaten by larger organisms, resulting in the contaminants being passed up the food chain in processes known as bioaccumulation. This process can result in concentrations of organochlorine compounds in fish and other biota that are harmful to wildlife and humans that consume them.

Concentrations of DDT and organochlorine insecticides in aquatic organisms and bed sediment still exceed guidelines for protection of fish-eating wildlife

Studies done during the 1970s and 1980s documented contamination of both stream bed sediments and aquatic organisms in the San Joaquin River system. In those studies, levels of organochlorine insecticides in the San Joaquin Valley were high compared with other parts of the Nation, and levels in aquatic organisms exceeded guidelines for the protection of fish-eating wildlife in several areas (Brown, 1997). In October 1992, samples of tissue of aquatic organisms and fine-grained bed sediment were collected at 18 sites and analyzed to determine whether the distribution or concentrations of organochlorine insecticides had changed from the earlier studies.

Concentrations of organochlorine insecticides in aquatic organisms and bed sediment were highest in the small western tributaries to the San Joaquin River and in the lower part of the San Joaquin River (Brown, 1997). Concentrations in these areas were still high compared to national values from the 1970s and 1980s. Concentrations in tissue and sediment at the west-side sites were among the highest encountered at NAWQA Study Units. Comparison of 1992 data with data that were available for some sites showed evidence of a decline in concentrations in tissue at those sites. Bed-sediment concentrations appeared similar to historical data, but the historical data were collected using different methods, making direct comparisons difficult. There was a strong correlation between concentrations of DDT in tissue (of clams and fish) and in bed sediment, suggesting that bioaccumulation was taking place (Brown, 1997).

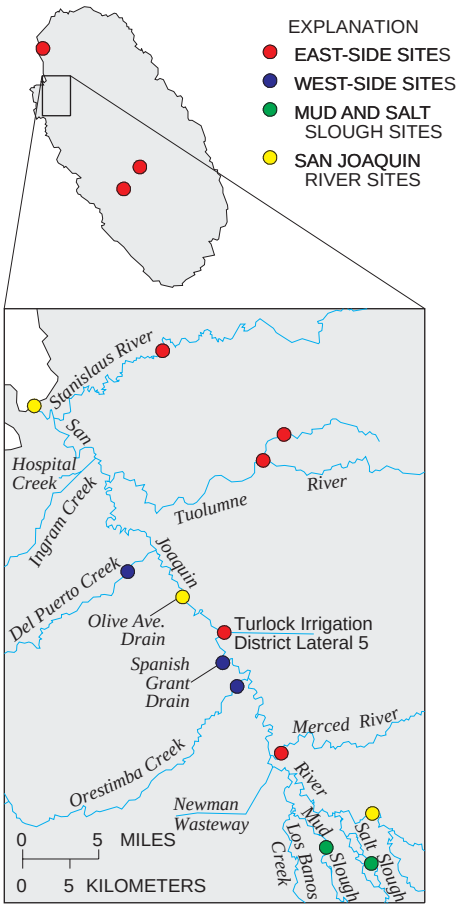
The results of these comparisons indicate that, though these insecticide concentrations might be declining, they may adversely impact aquatic organisms, and hence other wildlife, in the San Joaquin Valley for years to come. An additional potential impact of these compounds has been revealed by recent studies that suggest that organochlorine insecticides can be harmful to the hormone (endocrine) and immune systems of wildlife and humans at much lower concentrations than was previously thought (Colborn and Clement, 1992).

San Joaquin River sites (3 sites)		
Compound	Tissue	Bed Sediment
Total DDT	50–510	ND–13
Toxaphene	ND–160	ND
Dieldrin	ND–5	ND
Dacthal	ND–33	ND
PCBs	ND–57	ND

West-side sites (3 sites)		
Compound	Tissue	Bed Sediment
Total DDT	509–2,192	109–415
Toxaphene	ND–2,000	ND–630
Dieldrin	ND–10	1–10
Dacthal	11–360	ND–32
PCBs	ND–57	ND
Permethrin	NA	ND–31

East-side sites (8 sites)		
Compound	Tissue	Bed Sediment
Total DDT	6–101	ND–50
Chlordane	ND	ND–9

Mud and Salt Sloughs sites (2 sites)		
Compound	Tissue	Bed Sediment
Total DDT	79–342	1–7
Dieldrin	ND–6	ND



The concentration and variety of organochlorine insecticides in tissue and bed sediment were highest in west-side sites, intermediate in the San Joaquin River sites, and lowest in east-side sites. (Red values – exceeded guidelines for the protection of fish-eating wildlife [National Academy of Sciences and National Academy of Engineering, 1973]. NA – not analyzed; tissue and sediment values in micrograms per kilogram, wet and dry weight, respectively; ND – not detected).

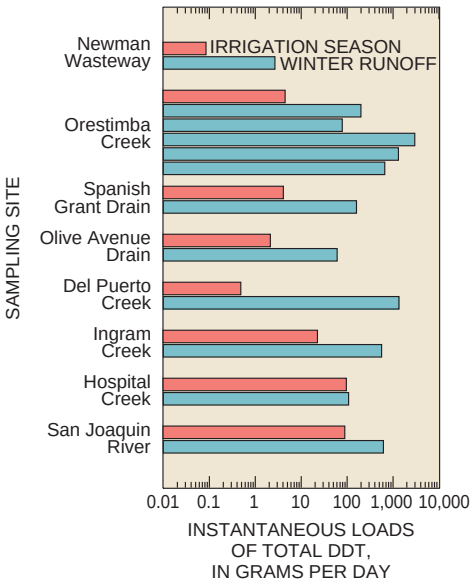
Large amounts of sediment-bound DDT and other organochlorine insecticides are transported from small west-side tributaries to the San Joaquin River during winter storms

NAWQA did studies on the west-side tributaries and main stem of the San Joaquin River to determine the processes controlling transport of sediment-bound pesticides. Samples of suspended sediment were analyzed for 15 organochlorine insecticides to compare transport during the irrigation season (June 1994) with transport during winter storm runoff (January 1995) (Kratzer, 1998).

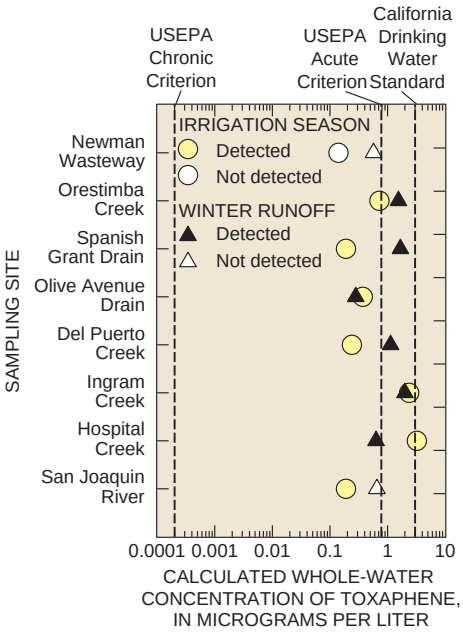
The most frequently detected organochlorine insecticides during both the winter storm runoff and irrigation season were *p,p´*-DDE, *p,p´*-DDT, *p,p´*-DDD, dieldrin, toxaphene, and chlordane. Aldrin, endrin, mirex, and lindane also were detected during the winter storm runoff; lindane was also detected during the irrigation season.

Median concentrations of total DDT, chlordane, dieldrin, and toxaphene on suspended sediment were slightly greater during the irrigation season than during winter storm runoff. However, streamflows, suspended-sediment concentrations, and instantaneous loads were substantially greater during the winter storm runoff.

Most of the calculated whole-water concentrations of *p,p´*-DDT, chlordane, dieldrin, and toxaphene exceeded the USEPA chronic criteria for the protection of freshwater aquatic life (U.S. Environmental Protection Agency, 1986). In addition, 6 of 16 toxaphene and 1 of 16 *p,p´*-DDT concentrations exceeded USEPA acute criteria for the protection of freshwater aquatic life (U.S. Environ-mental Protection Agency, 1986), and 5 of 16 chlordane and 1 of 16 toxaphene concentrations exceeded California drinking-water standards (California Department of Water Resources, 1995).



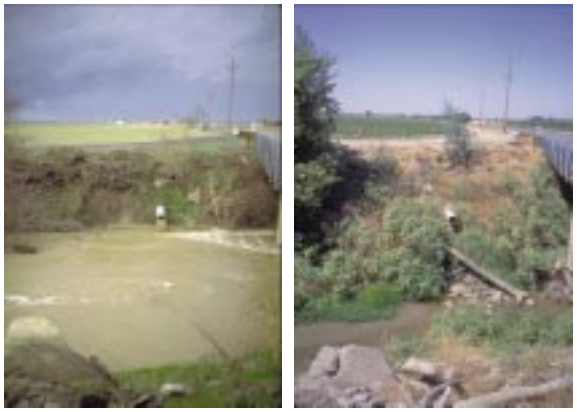
Loads of total DDT were substantially greater in samples collected during winter runoff compared with samples collected during irrigation season at all sites except Hospital Creek.



Most whole-water concentrations of toxaphene exceeded the USEPA chronic criterion for protection of freshwater aquatic life.

Although controlling irrigation-induced soil erosion will reduce the transport of organochlorine insecticides, it will not eliminate organochlorine insecticides from the San Joaquin River because of transport during winter storms

Estimated loads of organochlorine insecticides for the entire irrigation season exceeded estimated loads for the January 1995 storm by about 2 to 4 times for suspended transport and about 3 to 11 times for total transport. However, because the average winter runoff is 2 to 4 times the runoff during the January 1995 storm, average winter transport of organochlorine insecticides may be similar to irrigation season transport. The average winter transport is also dependent on long-term seasonal variations in suspended-sediment and organochlorine insecticide concentrations, both of which are unknown. Nevertheless, these findings indicate that runoff from winter storms will continue to deliver a significant load of sediment-bound organochlorine insecticides to the San Joaquin River for an indeterminate amount of time, even if irrigation-induced soil erosion is reduced.



Orestimba Creek during a winter storm (left) and irrigation season (right) (photographs by Sylvia V. Stork and Charles R. Kratzer, U.S. Geological Survey, respectively).

Nitrogen and phosphorus are essential nutrients for aquatic plants. However, in high concentrations, they can cause excessive plant growth (eutrophication) and toxicity to infants ("blue baby syndrome" or methemoglobinemia from ingestion of nitrate). The USEPA has set criteria for the nitrate and ammonia forms of nitrogen, but not for phosphorus. The maximum contaminant level (MCL) for nitrate in drinking water is 10 milligrams per liter as nitrogen (mg/L as N) (U.S. Environmental Protection Agency, 1986).

The USEPA also has established criteria for maximum ammonia concentrations in surface water on the basis of chronic and acute exposure of aquatic organisms to un-ionized ammonia (U.S. Environmental Protection Agency, 1986). These criteria vary inversely with pH and temperature. The chronic criteria range from about 0.2 to 2 mg/L as N for the range of pH (7.5–8.5) and temperatures (5–25°C) generally found in surface water in the San Joaquin Valley.

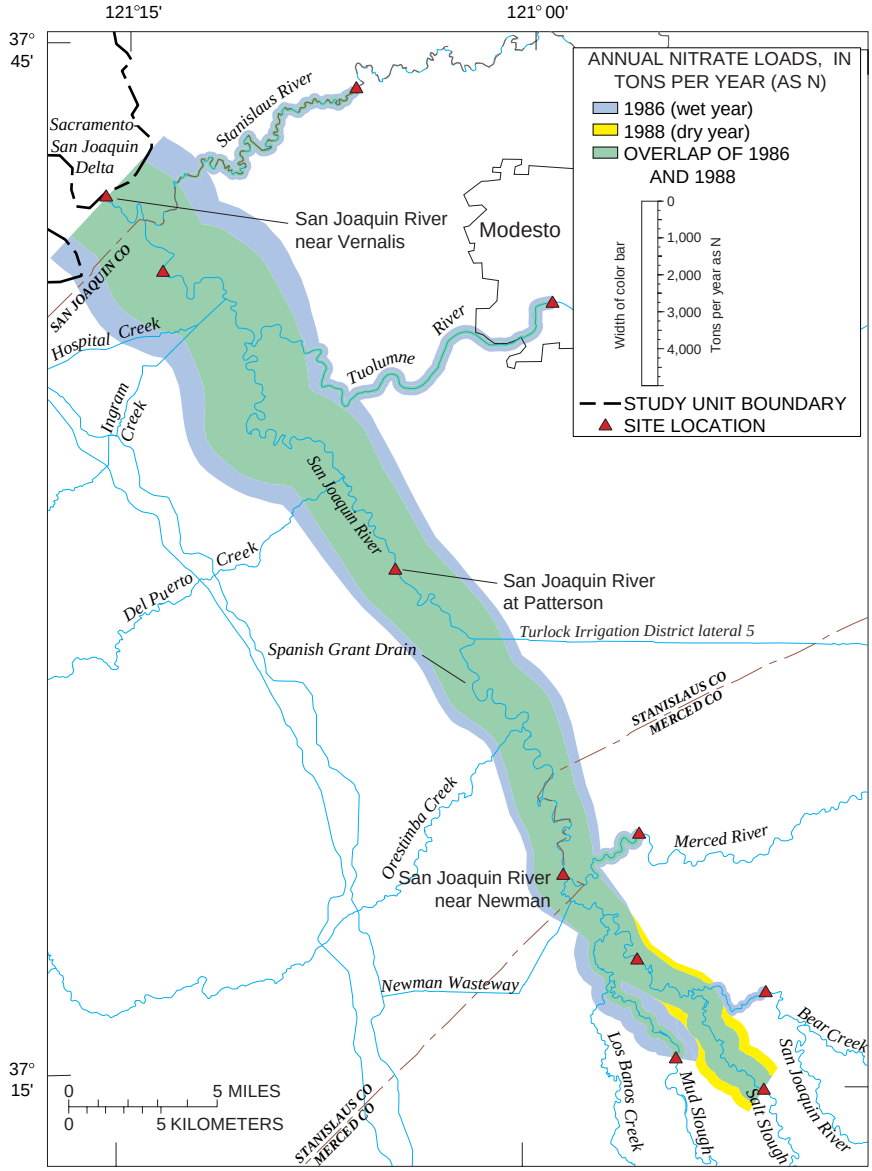
Mud and Salt Sloughs account for nearly half of the nitrate in the San Joaquin River

Nutrient concentrations in the lower San Joaquin River are determined primarily by relatively concentrated inputs from west-side agricultural drainage, east-side wastewater-treatment plants and runoff from dairies, and relatively dilute inputs from major east-side tributaries. Mud and Salt sloughs receive a part of their flow from subsurface drains that drain about 60,000 acres of agricultural land. Although the sloughs account for only about 10 percent of the streamflow in the San Joaquin River near Vernalis, the subsurface drainage is very high in nitrate (about 25 mg/L as N), and the sloughs contribute nearly one-half the nitrate (Kratzer and Shelton, in press). The nitrate transported in the San Joaquin River during a wet year (1986) was about 50 percent more than that transported in a dry year (1988).

The nitrate MCL was exceeded in Spanish Grant Drain, Turlock Irrigation District lateral 5, and Orestimba Creek in 15, 11, and 9 percent, respectively, of samples collected between April 1993 and March 1995. However, these tributaries are not designated as drinking-water sources. The MCL was not exceeded during this period in the main stem of the San Joaquin River, a designated drinking-water source.

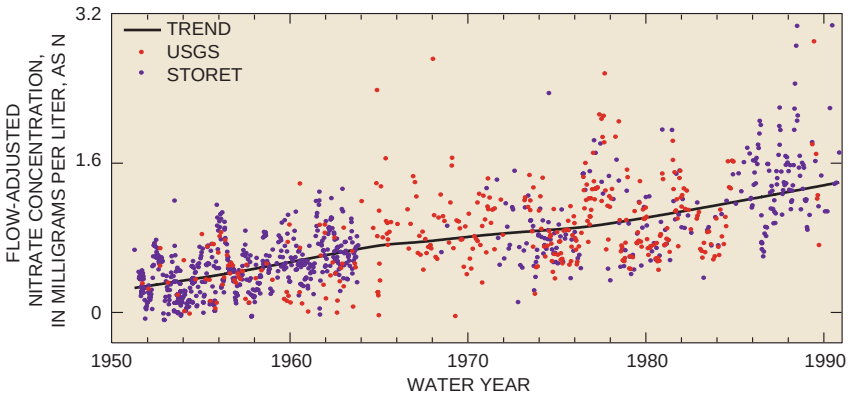
Nitrate concentrations in the San Joaquin River have been increasing during the last 40 years

Increasing nitrate concentrations in the San Joaquin River could be attributed to several sources, including subsurface agricultural drainage, runoff from fertilizer applications, wastewater-treatment plant effluent, and runoff from dairies. The relative contribution of these sources was evaluated with estimates of nitrate loads and with trends in ammonia and phosphorus concentrations. Wastewater- treatment plant effluent and runoff from dairies have especially high concentrations of ammonia and phosphorus, yet concentrations of ammonia and phosphorus in the San Joaquin River generally declined or remained stable while nitrate concentrations steadily increased.

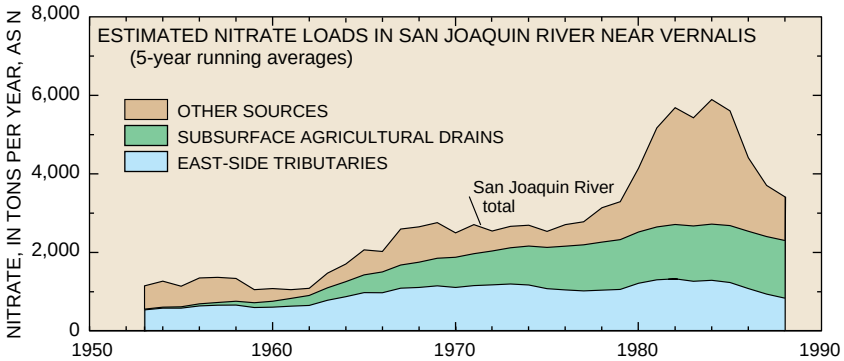


During both dry and wet years, much of the nitrate load in the San Joaquin River can be attributed to subsurface agricultural drainage discharged to Mud and Salt sloughs.

The source of the nitrate increase during the 1950s was indeterminate. During the 1960s, runoff from fertilizer applications (primarily in east-side basins) and subsurface agricultural drainage were the probable sources of the increase. Since 1970, subsurface agricultural drainage has been the primary cause of the increasing nitrate trend (Kratzer and Shelton, in press). Other studies have determined that the nitrate in the subsurface agricultural drainage primarily comes from the leaching of native soil nitrogen and not from fertilizer application (Brown, 1975). Other sources of nitrate loads were especially important in the early 1980s because of the effect of an extremely wet year (1983) on the 5-year running averages. The unusually large inputs of nitrate in 1983 were probably from (1) inflow from the Tulare Basin through the Fresno Slough, (2) discharge from wastewater-treatment plants, (3) runoff from dairies, and (4) runoff from fertilizer applications west of the San Joaquin River (Kratzer and Shelton, in press). Despite this long-term increase in the San Joaquin River, nitrate concentrations are still well below the USEPA drinking-water standard.



The flow-adjusted nitrate concentration in the San Joaquin River has increased from about 0.3 to 1.4 milligrams per liter (mg/L) over the last four decades.



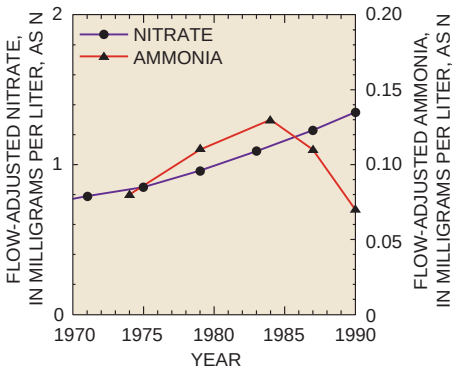
Nitrate loads in the San Joaquin River from subsurface agricultural drains have increased steadily since the 1950s.

Ammonia criteria were frequently exceeded in Turlock Irrigation District lateral 5 and occasionally exceeded in Orestimba Creek and Spanish Grant Drain

On the basis of monthly samples collected during 1985–88, ammonia concentrations in the San Joaquin River increased from Newman to Patterson, then declined from Patterson to Vernalis as a result of dilution by the Tuolumne and Stanislaus Rivers (Kratzer and Shelton, in press). The increase from Newman to Patterson is attributed to relatively concentrated inputs, such as Turlock Irrigation District lateral 5, Orestimba Creek, and Spanish Grant Drain. Most of the flow in Turlock Irrigation District lateral 5 is effluent from the Turlock wastewater-treatment plant, especially during the nonirrigation season. Ammonia concentrations exceeded the USEPA chronic criteria in 2 of the 51 samples collected at the San Joaquin River at Patterson during 1985–88.

Ammonia concentrations in Turlock Irrigation District lateral 5, Orestimba Creek, and Spanish Grant Drain exceeded the USEPA chronic criteria in 76, 14, and 5 percent, respectively, of samples collected between April 1993 and March 1995. None of the samples collected at the San Joaquin River at Patterson during April 1993 to March 1995 had ammonia concentrations that exceeded the USEPA chronic criteria, but some concentrations were just under the criteria.

Unlike nitrate, ammonia concentrations at the San Joaquin River near Vernalis did not increase from 1974 to 1990. Instead, ammonia concentrations increased until 1984, then declined. This decrease was probably due to a combination of factors, including conversion of ammonia to nitrate by improved wastewater treatment, reduced discharges from wastewater-treatment plants due to a sequence of dry years during the late 1980s and expanded use of land disposal, and reduced inputs from dairies during the sequence of dry years (Kratzer and Shelton, in press).



Nitrate concentration in the San Joaquin River have steadily increased while ammonia concentration has declined since 1984.

Human activities, including development of water resources, agriculture, and urbanization in the San Joaquin–Tulare Basins, have been accompanied by large-scale changes in aquatic ecosystems. Populations of anadromous salmon have declined, along with other migratory and resident native species. Though there are likely many reasons for the decline, the roles of water chemistry and habitat degradation have not been assessed on a basin-wide scale. Fish communities were sampled in the San Joaquin–Tulare Basins to determine their status and whether they provided useful indications of water chemistry and habitat conditions.

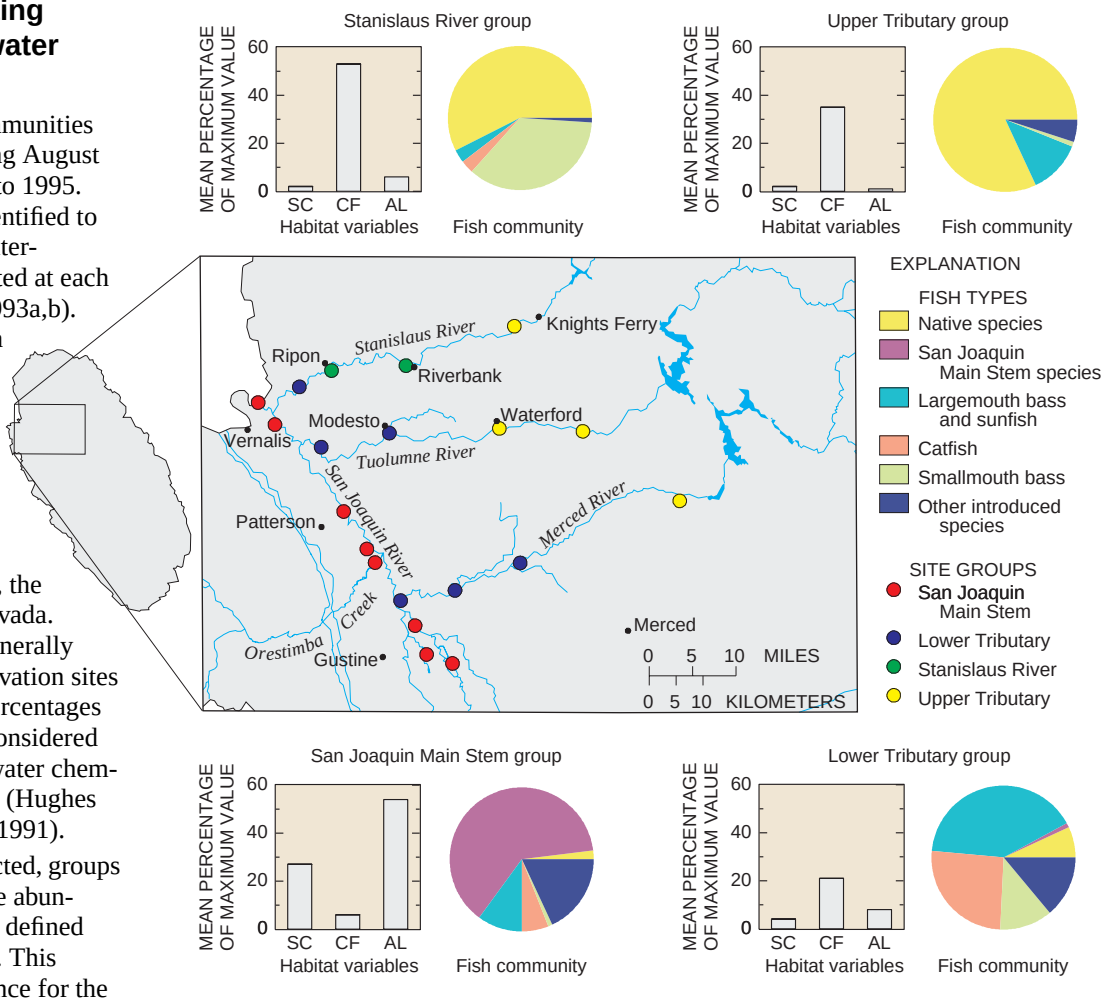
Introduced fish species outnumber native species almost 2 to 1, indicating impaired habitat or water chemistry or both

Assessments of fish communities were made at 32 sites during August and September from 1993 to 1995. Fish were collected and identified to species, and habitat and water-chemistry data were collected at each site (Meador and others, 1993a,b). A total of 34 species of fish were collected. Twelve species were native to California and 22 species were introduced from outside California. Native species were generally more abundant at higher elevation sites in the valley, the foothills, and the Sierra Nevada. Introduced species were generally more abundant at lower elevation sites on the valley floor. High percentages of introduced species are considered an indication of impaired water chemistry and habitat conditions (Hughes and Gammon, 1987; Karr, 1991).

Using the fish data collected, groups of sites with similar relative abundances of fish species were defined using statistical techniques. This analysis was done twice: once for the 20 low-elevation sites most likely to be affected by human activities, and once for all of the 32 sites sampled.

The 20 low-elevation sites were all in the lower San Joaquin River drainage, downstream from the major foothills reservoirs. Four groups of sites were identified on the basis of fish communities, water chemistry, and habitat quality: a San Joaquin Main Stem group, a Lower Tributary group, a Stanislaus River group, and an Upper Tributary group.

The San Joaquin Main Stem group was characterized by high percentages of introduced species tolerant of harsh environmental conditions, particularly the fathead minnow, red shiner, threadfin shad, and inland silverside (all referred to as the San Joaquin Main Stem species). The San Joaquin Main Stem group included eight sites on the main stem of the San Joaquin River and on small western and southern tributary streams. Specific conductance (an indicator of salinity), which was highest at these sites, is a good indicator of general water chemistry and of the influence of irrigation return flows in the San Joaquin River drainage. Fish cover—the percentage of area that provides cover from predators—was lowest at these sites. Environmental degradation, as indicated by increased specific conductance and decreased fish cover, was related to human activities such as agricultural land use. The Lower Tributary group was characterized by high percentages of introduced largemouth bass, redear sunfish, and white catfish. These sites were located in the lower and middle



At the 20 lower elevation sites, fish communities, habitat, and water chemistry varied significantly among the site groups. (SC – Specific conductance; CF – Cover for fish; AL – Agricultural land).

reaches of the Merced and Tuolumne Rivers, but only the farthest downstream site on the Stanislaus River. Values of specific conductance, fish cover, and agricultural land use were intermediate between the Upper Tributary and San Joaquin Main Stem groups.

The Upper Tributary group included the farthest upstream site on the Stanislaus and Merced Rivers, and the two farthest upstream sites on the Tuolumne River. These sites were characterized by high percentages of the native species: Sacramento squawfish, hardhead, Sacramento sucker, and prickly sculpin. Specific conductance and agricultural land use were lowest at these sites, and fish cover was highest.

The two middle sites on the Stanislaus River formed a separate group characterized by high percentages of introduced smallmouth bass and native tule perch. Water chemistry and habitat were similar to the Upper Tributary sites.

The second analysis, which was based on the fish data from all 32 sites, also resulted in four groups of sites: a San Joaquin Main Stem group, a Foothill group, a Lower Tributary group, and a Sierra Nevada group. The San Joaquin Main Stem group was identical and the Lower Tributary group very similar to the groups obtained using 20 sites. The Foothill group included all but one site in the previously defined Upper Tributary group, the Stanislaus River group, and additional sites located upstream from the foothill reservoirs. These sites were characterized by native Sacramento squawfish, hardhead, tule perch, scul-pins, and introduced smallmouth bass. The Sierra Nevada group was dominated by native rainbow trout and introduced brown trout. Water chemistry and habitat conditions were very different among site groups, as would be expected in a study that included small, cold, high-elevation streams and large, warm, low-elevation rivers. Thus, these groups are most indicative of large-scale, natural gradients and less related to environmental impairment than the groups obtained from the analysis of 20 low-elevation sites.

Riparian and instream habitats are good at Orestimba Creek, but because water chemistry is poor and fluctuations in flow are substantial, the site had a high percentage of introduced fish species (photograph by Larry R. Brown, U.S. Geological Survey).

Native species are more successful in the major eastern tributaries when flows are higher

Overall environmental quality is reflected by fish communities: native species are common at the least altered sites, and tolerant introduced species are common at the most altered sites. However, the influences of water chemistry and habitat on fish communities could not be separated because both sets of variables were related to land use (Brown and others, in press). Additional variables may also contribute to this pattern. Dissolved pesticide concentrations sometimes reached levels toxic to some invertebrates, primarily at sites in the San Joaquin Main Stem group. Similarly, concentrations of organochlorine insecticides in sediments and tissues of biota were highest at sites in the San Joaquin Main Stem group (Brown, 1997). The dominance of tolerant introduced species at the San Joaquin main stem sites is consistent with these patterns.

Environmental degradation due to human activities may have been stressful to resident fish as indicated by the high incidence of external abnormalities, such as parasites and lesions, at the Lower Tributary sites (21 percent) and San Joaquin main stem sites (17 percent). The incidence of abnormalities was much lower at the Stanislaus River (3 percent) and Upper Tributary sites (3 percent). In other areas of the country, an incidence of external abnormalities greater than 2 percent is considered an indicator of impaired conditions (Hughes and Gammon, 1987; Karr, 1991).

The rarity of native fishes at the Lower Tributary and San Joaquin main stem sites may not be irreversible. High discharges in 1995 in the Merced and Tuolumne Rivers were accompanied by higher percentages of resident and migratory native species. Statistical analysis of data from sites sampled in more than one year indicated that fish communities in 1993 and 1994 were very similar, but in 1995 were very different from the other years. Also, the greater abundance of native species in the Stanislaus River, particularly tule perch, at downstream sites compared with the other eastern tributaries, suggests that the higher summer flows favor native species. Further monitoring during different flow conditions could help determine conditions necessary to reestablish native fish communities.

This site on the Stanislaus River has good riparian habitat, instream habitat, and water chemistry (photograph by Larry R. Brown, U.S. Geological Survey).

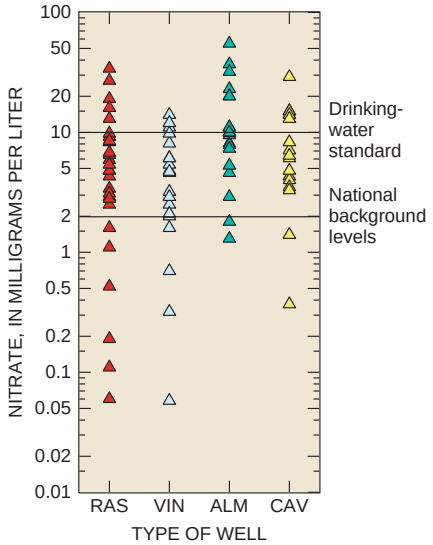
Ground water is the source of drinking water for most of the population of the eastern San Joaquin Valley. Each year, millions of pounds of nitrate (in fertilizer and manure) and pesticides are applied to cropland. Some of these chemicals infiltrate to the water table, degrade the water quality, and potentially cause a public health risk.

The quality of ground water in the alluvial fans of the eastern San Joaquin Valley was assessed by collecting data from three sets of wells: 30 domestic wells representative of the regional aquifer, 60 shallow domestic wells in three well-defined and contrasting agricultural land-use settings, and 20 multilevel monitoring wells in a 3.5-mile transect along a ground-water flow path (*see* p. 24–25).

Nitrate concentrations in ground water in the eastern San Joaquin Valley often exceeded the drinking-water standard

Nitrate concentrations in 24 percent (21 of 88) of the domestic wells sampled during 1993–95 in the regional aquifer survey and land-use studies of the eastern San Joaquin Valley exceeded the drinking-water standard of 10 mg/L established by the USEPA. Furthermore, ground-water samples from 77 percent of the wells had nitrate concentrations greater than 2 mg/L, which is believed to represent background concentrations (Mueller and Helsel, 1996). These findings indicate that ground-water quality has been degraded over a large part of this aquifer because of the input of nitrate from human activity.

Ground-water samples collected in 1995 from the 30 domestic wells in the regional aquifer survey (median well depth 182 feet) had a median nitrate concentration of 4.6 mg/L; 5 of the 30 wells (17 percent) exceeded the USEPA drinking-water standard. The median concentration of 4.6 mg/L was higher than the median of 2.4 mg/L for ground water in similar alluvial settings with agricultural land use nationwide (Mueller and others, 1995).



Nitrate concentrations in 24 percent of domestic wells exceeded USEPA drinking-water standards (RAS – regional aquifer survey; VIN – vineyard land use; ALM – almond land use; CAV – corn, alfalfa, and vegetable land use).

Nitrate concentrations in ground water sampled during 1993–95 from shallow domestic wells (median well depth 150 feet) were compared among three contrasting agricultural land-use settings. These 60 wells (three sets of 20) represent a part of the aquifer that is usually used as a domestic water supply. Nitrate concentrations were the highest in samples from the wells in the almond land-use setting, whereas concentrations were the lowest in samples from wells in the vineyard land-use setting. Nitrate concentrations were intermediate in samples from a grouped land-use setting of corn, alfalfa, and vegetables. Median nitrate concentrations in the three land-use settings were greater than or equal to the median in the regional aquifer survey; therefore, some of the other land-use settings in the eastern San Joaquin Valley must have generally lower nitrate concentrations than these three agricultural settings.

Nitrate concentrations in samples from shallow domestic wells were related to nitrate application, sediment texture, and potential for nitrate removal by chemical reactions

Sources of nitrate from agriculture—fertilizer and manure—were estimated for a 0.25-mile-radius circle centered at each well in each of the three agricultural land-use settings. Nitrate concentrations in ground water in the three land-use settings were related to estimates of the amount of nitrogen applied: the greatest amount of nitrogen was applied in the almond land-use setting; a slightly lower amount was applied in the corn, alfalfa, and vegetable land-use setting; and the smallest amount was applied in the vineyard land-use setting (Burow and others, in press, a). The estimated amount of nitrogen applied to individual sites was not strongly related to nitrate concentrations in ground-water samples from the wells, however. These results indicate that estimates of the amount of nitrogen applied are a fair indicator of nitrate concentrations for an area; however, the estimates are not a good predictor of concentration in an individual well.

This lack of predictability probably is due to several factors. The amount

Nitrate sources and aquifer susceptibility vary in the three agricultural land-use settings.

Characteristic	Vineyard	Almond	Corn, alfalfa, vegetables
Median nitrate concentration, in milligrams per liter (number of samples that exceeded the USEPA drinking-water standard in parenthesis)	Low 4.6 (3)	High 10 (8)	Intermediate 6.2 (7)
Source: nitrogen applied within a 0.25-mile radius	Low 7,300 lb	High 19,900 lb	High 16,400 lb
Susceptibility: sediment texture	High	High	Low
Susceptibility: potential for nitrate removal by chemical reactions (nitrate reduction)	Low	Intermediate	High

of coarse-grained sediments (sand- or gravel-sized) in the subsurface, which is referred to as sediment texture, is a major factor in the susceptibility of a site to nitrate contamination. The sediment texture influences the rates of infiltration and ground-water flow in the aquifer, which controls how rapidly water at the surface, with high nitrate concentrations, can infiltrate the soil and move downward to a well in the aquifer. The sediment textures in the almond and vineyard land-use settings were generally coarse-grained and conducive to rapid infiltration and ground-water flow. The sediment texture in the corn, alfalfa, and vegetable land-use setting was generally fine-grained with abundant clay, resulting in slow rates of infiltration and ground-water flow.

These contrasts in sediment texture, considered along with the contrasts in the amount of nitrogen applied, indicate that nitrate concentrations in ground water were highest where high susceptibility and high amounts of nitrogen applied occurred together (the almond land-use setting); nitrate concentrations in ground water were lowest where the amount of nitrogen applied was low, even though the susceptibility was high (the vineyard land-use setting); and nitrate concentrations in ground water were intermediate where the amount of nitrogen applied was high, but the susceptibility was low (the corn, alfalfa, and vegetable land-use setting) (Burow and others, in press, a).

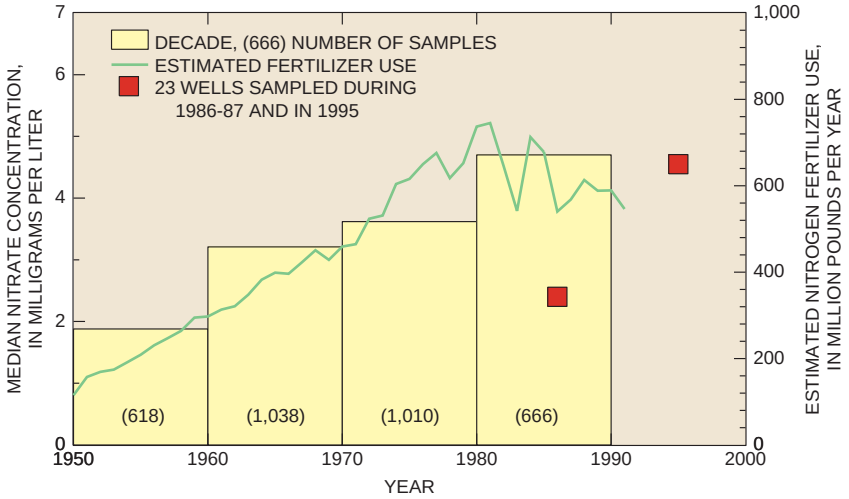
Nitrate in ground water can also be removed by biochemical reactions such as nitrate reduction, in which nitrate is converted to nitrogen gas. These biochemical reactions can happen in ground water that has very low concentrations of dissolved oxygen. The chemical traits that indicate a potential for nitrate reduction, such as low dissolved-oxygen concentrations and high concentrations of iron and manganese, existed in ground-water samples from the corn, alfalfa, and vegetable land-use setting. The few samples that have these chemical traits do in fact have low or nondetectable nitrate concentrations. In contrast, there is little evidence of nitrate reduction in samples from the almond and vineyard land-use settings. Therefore, ground water in parts of the corn, alfalfa, and vegetable land-use setting is less susceptible to nitrate contamination than ground water in the other two land-use settings because nitrate may be removed by biochemical processes.

The presence of fine-grained sediment textures and evidence of nitrate reduction at some sites in the corn, alfalfa, and vegetable land-use setting are a result of its location on the lowest parts of the eastern alluvial fans, near the boundary between the alluvial fans and basin, where sediments were deposited by different sedimentary processes. As a result, sediment texture and chemical conditions in the corn, alfalfa, and vegetable land-use setting are more variable than in the almond and vineyard land-use settings. This high variability makes it difficult to generalize the conclusions from the overall data set to specific sites.

Nitrate concentrations in ground water have increased in the eastern San Joaquin Valley

Analyses of several thousand ground-water samples were compiled from USGS and USEPA data bases to evaluate the long-term changes in nitrate concentrations. Data from wells in the eastern San Joaquin Valley that were less than or equal to 200 feet deep indicate that median nitrate concentrations increased significantly from the 1950s to the 1960s, and from the 1970s to the 1980s. From 1950 to 1980, the amount of nitrogen fertilizer applied in the eastern San Joaquin Valley counties increased from 114 to 745 million pounds per year, an increase of 554 percent. The number of dairies and other confined-animal feedlots, and hence manure production, also have increased greatly during this period. However, estimates indicate that nitrogen fertilizer is the largest source of nitrate in the eastern San Joaquin Valley (Gronberg and others, in press). Of course, this generalization may not be the case for areas where the source may be attributed to confined-animal feedlots located close together.

As indicated by a much smaller but better controlled data set, nitrate concentrations increased over less than a decade. Of the 30 wells in the regional aquifer survey in the eastern San Joaquin Valley that were sampled in 1995, 23 also had been sampled during 1986–87. The median nitrate concentration of this subset of 23 domestic wells increased from 2.4 mg/L during 1986–87 to 4.8 mg/L in 1995 (Burow and others, in press, b). The increase in

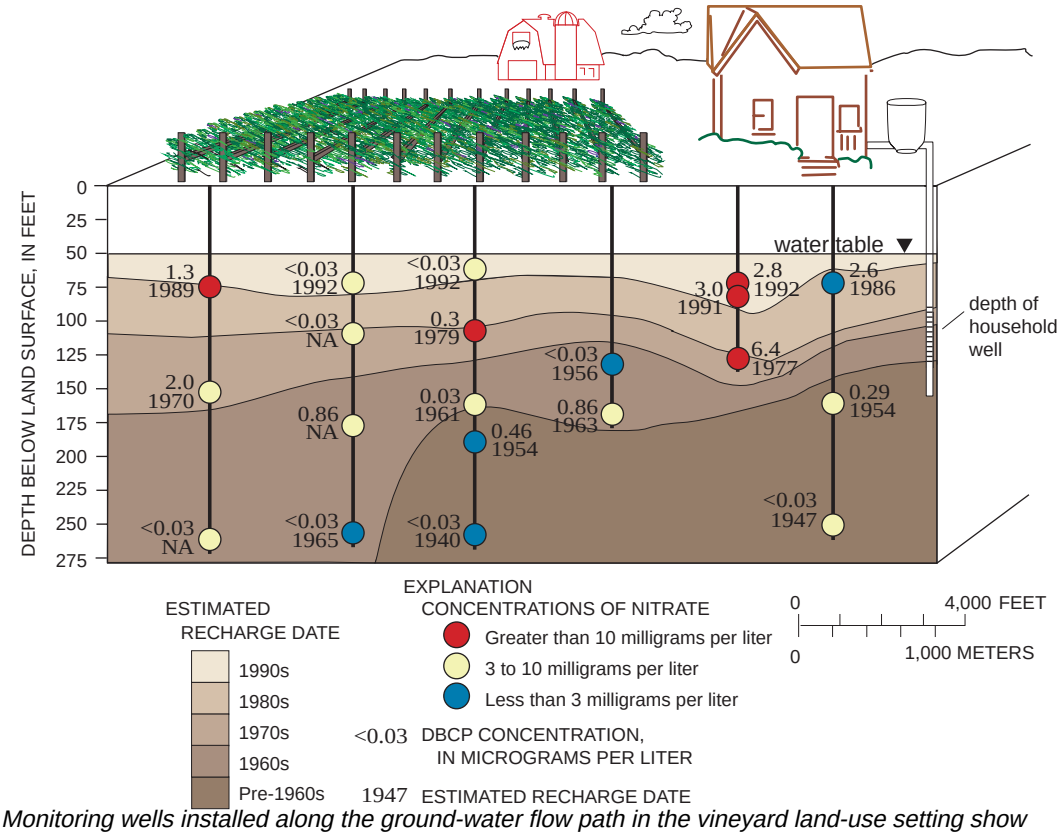


Fertilizer use and median nitrate concentration in ground water have generally increased over the past four decades.

nitrate concentration is likely attributed to increased fertilizer use from 1950 to 1980.

Analyses of samples from the 20 multilevel monitoring wells in the vineyard land-use setting indicated that nitrate concentrations have generally increased over the last four decades. In addition to analyses for nitrate and pesticides, the estimated date when the ground water sampled from these wells was recharged was determined by measuring concentrations of chlorofluorocarbons (CFC). CFC concentrations in samples from the deepest wells indicate that the deepest ground water had entered the aquifer prior to 1960. Nitrate concentrations in the pre-1960 water are generally less than 3 mg/L. In general, ground-water age increases with depth below land surface, whereas nitrate concentrations decrease with depth. The highest nitrate concentrations occur in shallow ground water that was recharged during 1977 to 1992. Because typical domestic well depths in the vicinity of the monitoring well transect are about 90 to 130 feet below land surface, these data suggest that nitrate concentrations could increase in domestic wells in the vineyard land-use setting.

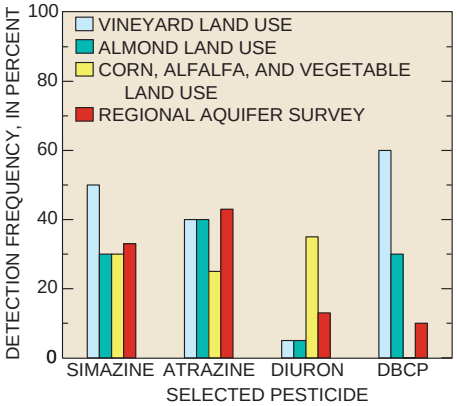
Taken together, these studies offer compelling evidence that nitrate concentrations in the ground water in the eastern San Joaquin Valley have increased over the last four decades; prediction of future change is problematic because of the decrease in the amount of fertilizer application over the last decade.



Monitoring wells installed along the ground-water flow path in the vineyard land-use setting show that DBCP and nitrate concentrations generally are lowest in older water and are high but variable in the younger water (<, less than).

Pesticides were detected in 69 percent of the ground-water samples collected from domestic wells in the eastern San Joaquin Valley

Pesticides were detected in 61 of the 88 domestic wells sampled during 1993–95 (69 percent), but concentrations of most pesticides were low—less than 0.1 µg/L. Although 25 pesticides were detected, only 5 pesticides were detected in more than 10 percent of the samples: simazine, 1,2-dibromo-3-chloropropane (DBCP), atrazine, desethylatrazine (a transformation product of atrazine), and diuron. The greatest number of pesticides were detected in ground-water samples from wells in the vineyard land-use setting, where 17 different pesticides were detected in 80 percent of the samples. Pesticides were detected least often (in 55 percent of samples) in ground-water samples from wells in the corn, alfalfa, and vegetable land-use setting, although the number of pesticide detections were not significantly different among the three land-use settings.



Simazine, atrazine, diuron, and DBCP are the most common pesticides in the eastern San Joaquin Valley, California (atrazine detections include desethylatrazine).

The occurrence of DBCP and simazine in the three agricultural land-use settings is generally consistent with the available information on the use of these pesticides (Burow and others, in press, a). In contrast, atrazine and diuron detections were not consistent with their reported use, possibly because of their application on rights-of-way for weed control.

The number of pesticide detections was related to characteristics that dictate the relative susceptibility of ground water beneath the three land-use settings. The greatest number of pesticide detections occurred in the vineyard land-use setting. The number of pesticide detections per sample was correlated with the coarse-grained sediment texture and dissolved-oxygen concentrations. Furthermore, samples from 15 of the 18 (83 percent) wells with nitrate concentrations exceeding the USEPA drinking-water standard also contained at least one pesticide. In the vineyard land-use setting, concentrations of DBCP and nitrate were positively correlated, indicating that ground-water samples with the highest nitrate concentrations also had the highest DBCP concentrations.

DBCP concentrations exceeded the USEPA drinking-water standard in 20 percent of the ground-water samples collected from domestic wells in the eastern San Joaquin Valley

Concentrations of DBCP, a soil fumigant banned since 1977, exceeded the USEPA drinking-water standard of 0.2 µg/L in 18 of the 88 (or 20 percent) domestic wells sampled during 1993–95. Ten of the DBCP samples that exceeded the USEPA standards were from wells in the vineyard land-use setting, where DBCP was used to combat nematodes. In contrast, DBCP was not detected in any of the samples from the wells in the corn, alfalfa, and vegetable land-use setting. The soil fumigant 1,2-dibromoethane (also called EDB or ethylene dibromide) was the only other pesticide detected at a concentration that exceeded a USEPA drinking-water standard, although only six of the pesticides detected in ground water in the eastern San Joaquin Valley have drinking-water standards. EDB was detected in one ground-water sample.

Pesticide concentrations in domestic wells were consistent over time (1986–87 to 1995) but were higher in monitoring wells near the water table than at greater depths

Of the 30 domestic wells sampled as part of the regional aquifer survey in 1995, 19 had been sampled for pesticides during 1986–87. Samples from both periods were tested for 21 pesticides and 37 volatile organic compounds (VOC), but the laboratory methods of analyses were different for the two time periods. An increase from 13 pesticide detections during 1986–87 to 23 pesticide detections in 1995 can be attributed to the use of an analytical method that was 10 times more sensitive than the method used during 1986–87 (Burow and others, in press, b). If the data are adjusted to the same level of sensitivity, the number of pesticide detections is similar for the two periods: 10 detections during 1986–87 and 7 detections in 1995. Concentrations of pesticides generally were lower in 1995 than during 1986–87. Although the number of wells resampled is small, and the age of the sampled ground water has not been determined, there is no evidence that the pesticide concentrations or the number of pesticides detected during 1986–87 increased in 1995.

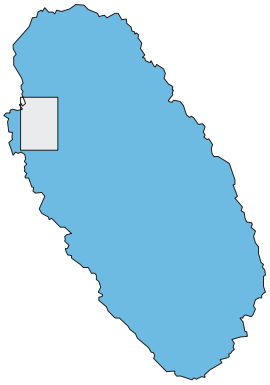
Analyses of samples from the 20 multilevel monitoring wells in the vineyard land-use setting show that DBCP concentrations generally decreased with depth and were highly variable near the water table. Pesticides were detected most frequently near the water table in ground water that was recharged after 1980. Simazine was detected in all six ground-water samples from shallow wells (less than 90 feet deep), atrazine (or desethylatrazine) was detected in five of the six shallow wells, and DBCP was detected in four of the six shallow wells. Although plausible explanations exist for the high DBCP concentrations in young ground water, current data are insufficient to confirm the source of the high DBCP concentrations. These data suggest that ground water from domestic wells in the vineyard land-use setting would likely continue to contain DBCP, simazine, and atrazine (or desethylatrazine).

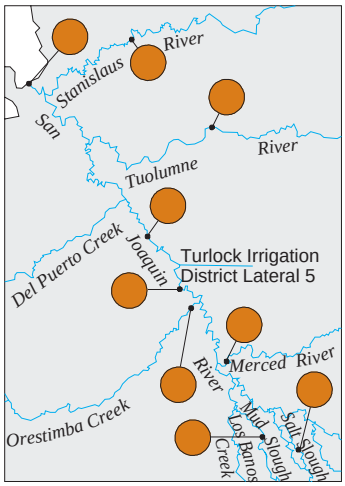
*The number of pesticide detections is similar during 1986–87 and 1995 (red – concentration remained the same or decreased; blue – concentration increased; white – indeterminate; * – estimated. <, less than; µg/L, micrograms per liter)*

Pesticide	1986-87 concentration (µg/L)	1995 concentration (µg/L)
Atrazine	<0.1	0.02
	<0.1	0.056
	0.1	0.007
	<0.1	0.002
	<0.1	0.12
	0.4	0.081
	<0.1	0.003
	0.2	0.009
Simazine	<0.1	0.059
	0.2	0.01
	<0.1	0.002
	0.1	0.095
	<0.1	0.006
	0.1	0.11
	<0.1	0.049
	0.2	0.009
	0.1	<0.005
	0.2	0.075
DBCP	<3.0	1.1
1,2-dichloropropane	6.4	0.4
Prometon	<0.1	0.008*
	<0.1	0.004*
Cyanazine	<0.1	0.023
EDB	<0.2	0.55
Dicamba	0.01	<0.035
	0.01	<0.035
Dichlorprop	0.01	<0.032

Seven major water-quality characteristics were evaluated for stream sites in each NAWQA Study Unit. Summary scores for each characteristic were computed for all sites that had adequate data. Scores for each site in the San Joaquin–Tulare Basins Study Unit were compared with scores for all sites sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared with other NAWQA sites. Water-quality conditions at each site also are compared to established criteria for protection of aquatic life. Applicable criteria are limited to nutrients and pesticides in water and semivolatile organic compounds (SVOC), organochlorine pesticides, and PCBs in sediment. (Methods used to compute rankings and evaluate aquatic-life criteria are described by Gilliom and others, in press.)

STUDY AREA showing inset





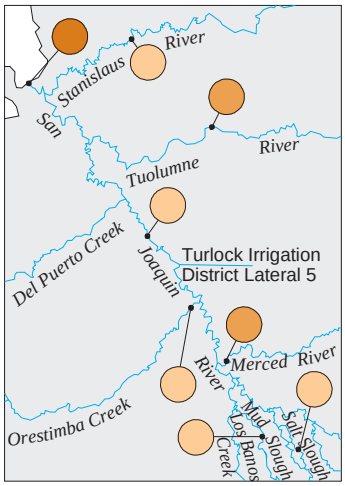
FISH COMMUNITY DEGRADATION

High percentages of fish at sites in the fixed-site network were nonnative, omnivores, diseased or deformed, or tolerant of human-caused stream degradation. Disease or deformity includes external parasites, tumors, and skeletal deformities. All sites received the poorest score for percentage of non-native species and percentage of fish with external anomalies. Fish communities at all sites were scored as highly degraded when compared with fish communities at other sites across the Nation.

EXPLANATION

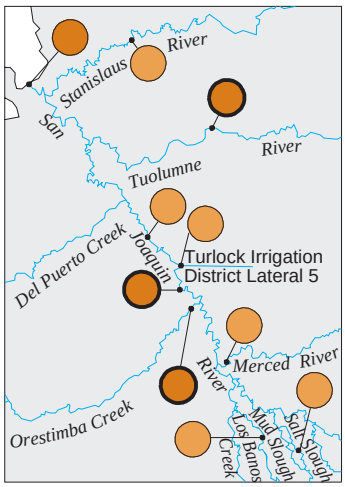
Ranking of stream quality relative to all NAWQA stream sites — Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more aquatic life criteria were exceeded.

- **Greater than the 75th percentile** (among the highest 25 percent of NAWQA stream sites)
- **Between the median and the 75th percentile**
- **Between the 25th percentile and the median**
- **Less than the 25th percentile** (among the lowest 25 percent of NAWQA stream sites)



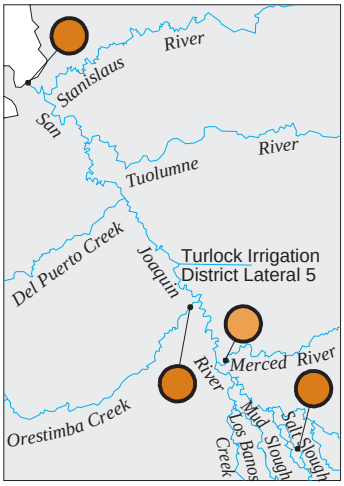
STREAM HABITAT DEGRADATION

Physical characteristics of streams can have substantial effects on water chemistry and aquatic life. On the basis of stream modification, bank erosion, bank stability, and riparian vegetation density, sites in the Study Unit were moderately to highly degraded when compared with other sites in the Nation. There are no standards or guidelines that apply to stream habitat.



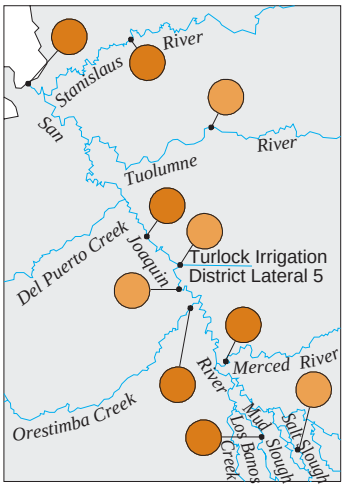
ORGANOCHLORINE PESTICIDES and PCBs in bed sediment and biological tissue

Concentrations of organochlorine chemicals in the Study Unit, particularly DDT compounds and toxaphene, were high in bed sediment and tissues of fish or clams. Levels at some sites were among the highest in the Nation.



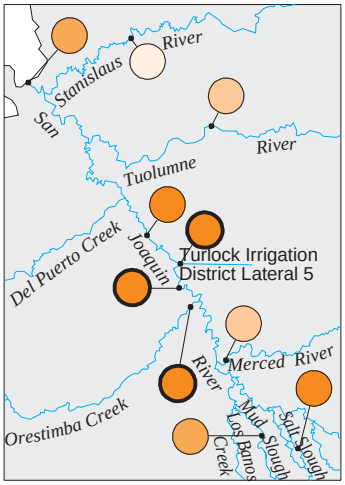
PESTICIDES in water

Concentrations of dissolved pesticides in the Study Unit were among the highest of all NAWQA sites nationwide. For many pesticides, this Study Unit had the maximum concentration of all 20 Study Units. All sites exceeded the aquatic-life criteria for at least one pesticide at least 17 percent of the time. However, drinking-water-quality standards were not exceeded.



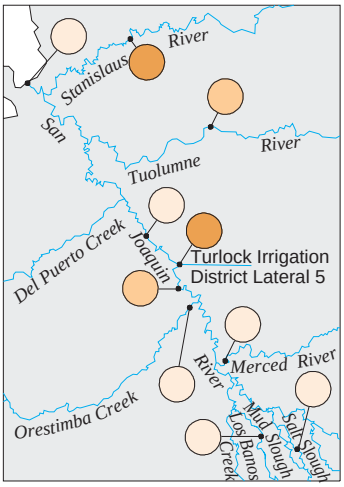
TRACE ELEMENTS in bed sediment

Concentrations of trace elements in bed sediment generally were higher than concentrations found in other NAWQA Study Units.



NUTRIENTS in water

Nutrient concentrations in the Study Unit ranged from very low to one of the highest in the Nation. The high concentrations occur at sites that are downstream from agricultural drainage or wastewater-treatment plant discharge. Ammonia concentrations exceeded guidelines for fish toxicity at three sites in the Study Unit.



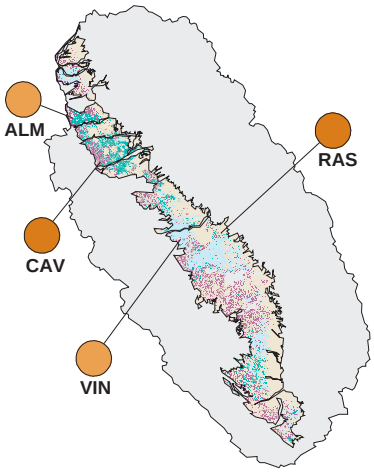
SEMIVOLATILE ORGANIC COMPOUNDS in bed sediment

Few SVOCs were detected in the Study Unit. Those detected were usually found at low concentrations, and values were low compared with other sites in the Nation. Criteria for protection of aquatic life were not exceeded.

CONCLUSIONS

The Study Unit is in poor condition compared with the other 19 Study Units in the categories of fish communities, PCBs, and organochlorines in streambed sediment and fish tissue, and pesticides in the water. Several sites exceeded guidelines and criteria, and the occurrence of nonnative fish species and fish with external anomalies were especially high in the Study Unit. Stream habitat and nutrient concentrations in water were close to the median for the 20 Study Units. Only the occurrence and concentrations of SVOCs in sediment were low relative to the other Study Units.

Five major water-quality characteristics were evaluated for ground-water studies in each NAWQA Study Unit. Ground-water resources were divided into two categories: (1) drinking-water aquifers, and (2) shallow ground water underlying agricultural or urban areas. Summary scores were computed for each characteristic for all aquifers and shallow ground-water areas that had adequate data. Scores for each aquifer and shallow ground-water area in the San Joaquin-Tulare Basins Study Unit were compared with scores for all aquifers and shallow ground-water areas sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared with other NAWQA ground-water studies. Water-quality conditions for each drinking-water aquifer also are compared with established drinking-water standards and criteria for protection of human health. (Methods used to compute rankings and evaluate standards and criteria are described by Gilliom and others, in press.)



RADON

Radon concentrations were relatively high when compared with other NAWQA Study Units. No current water-quality standards exist for this element.

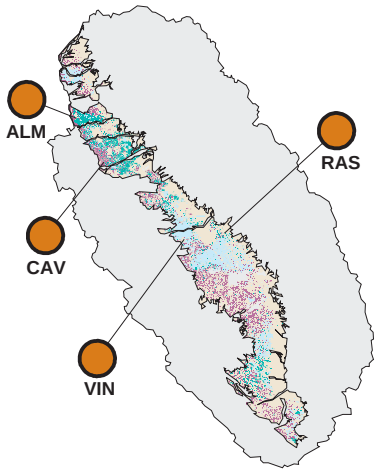
EXPLANATION

REGIONAL AQUIFER SURVEY (RAS)
(includes all land uses)

- Unspecified land use
- Almonds land use (ALM)
- Vineyards land use (VIN)
- Corn, alfalfa, vegetables land use (CAV)

All of these land-use settings represent both shallow ground water areas and drinking-water aquifers. For national comparison purposes, these land-use settings were compared with the summary scores of other drinking-water aquifers.

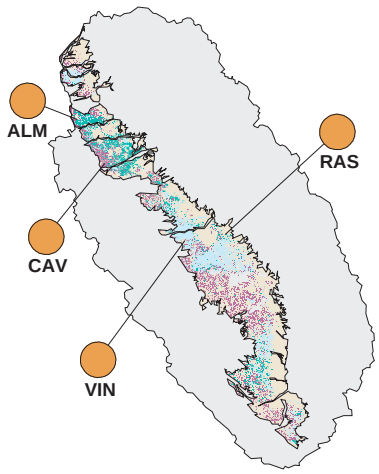
Ranking of ground-water quality relative to all NAWQA ground-water studies — Darker colored circles generally indicate poorer quality. Bold outline of circle indicates that one or more standards or criteria were exceeded.



NITRATE

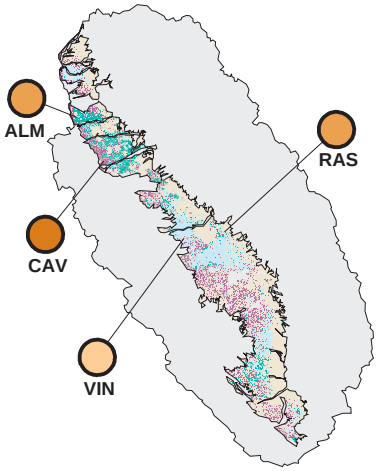
Nitrate concentrations in shallow ground water from domestic wells in agricultural areas were among the highest of all NAWQA Study Units. The water quality was different in areas with different crops. Drinking-water standards were exceeded in 40 percent of the wells in the almond area, and in only 15 percent of wells in the vineyard area.

- **Greater than the 75th percentile** (among the highest 25 percent of NAWQA ground-water studies)
- **Between the median and the 75th percentile**
- **Between the 25th percentile and the median**
- **Less than the 25th percentile** (among the lowest 25 percent of NAWQA ground-water studies)



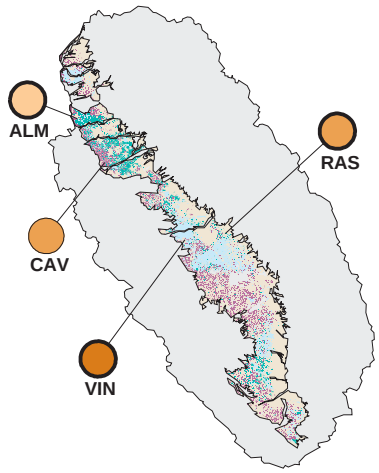
PESTICIDES

Pesticides were detected in more than 50 percent of ground-water samples in the Study Unit. All aquifer areas sampled had levels above the national median for NAWQA studies, but were not among the highest in the Nation. No drinking-water standards were exceeded, except for DBCP (see VOC results below).



DISSOLVED SOLIDS

Concentrations of dissolved solids in the eastern alluvial fans generally were higher than the median for all NAWQA Study Units; however, dissolved solids in areas where corn, alfalfa, and vegetables are grown were among the highest. The dissolved-solids standard is for aesthetics—appearance and smell—and though often exceeded, no health threat is indicated.



VOLATILE ORGANIC COMPOUNDS

VOCs were detected in 27 percent of the wells overall, and the percent detection in most of the areas was greater than the median for all NAWQA Study Units. The high rate of VOC detection and the exceedance of the drinking-water standard in 40 percent of the wells in the vineyard area are largely the result of the detection of the banned soil fumigant DBCP.

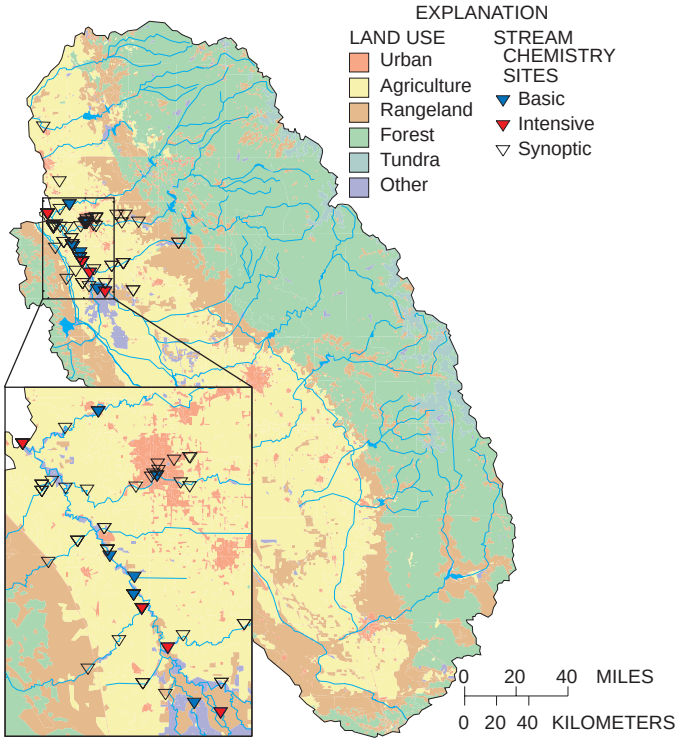
CONCLUSIONS

Ground-water quality in the San Joaquin–Tulare Basins is generally poor compared with the other Study Units. Nitrate concentrations were higher than the national median and frequently exceeded drinking-water standards in all of the four areas sampled. Pesticides were frequently detected and the rate of detection was above the national median. No drinking-water standards were exceeded. The rate of detection for VOCs was high compared to the other Study Units because of the frequent detection of DBCP. No drinking-water standards were exceeded except for DBCP, and in one sample, EDB.

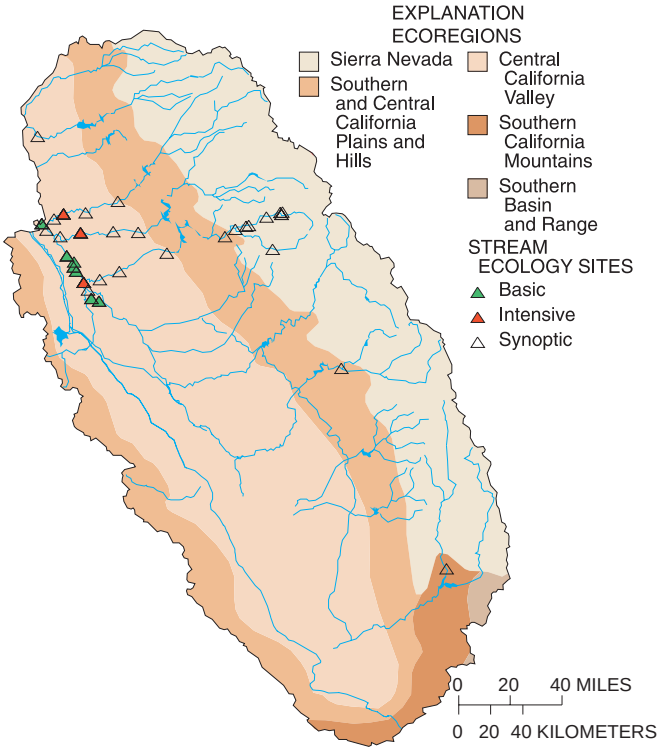
Sampling sites were selected to represent major, large-scale contrasts in ecoregions, land use, and hydrogeology. Most of the data were collected in the predominantly agricultural San Joaquin Valley because factors likely to impact water quality are concentrated in this area. This focus was consistent with the first two topics selected for study at the national level by the NAWQA Program: pesticides and nutrients.

Studies were designed to provide multiple lines of evidence to describe water quality conditions (Gilliom and others, 1995). To this end, investigations of surface-water chemistry, contaminants in sediment and in tissues of aquatic organisms, and aquatic ecology took place at the same sites, if possible. The studies also were designed to provide information on water quality over a range of complementary temporal and geographic scales. The time scale of surface-water investigations varied from once-a-year, to once-a-month, to several times a day. The geographic scale of the ground-water investigations ranged from sampling 30 wells distributed over 2,000 square miles to sampling four wells within 200 feet. Each scale of study revealed relations between water quality and causal factors not apparent at larger or smaller scales.

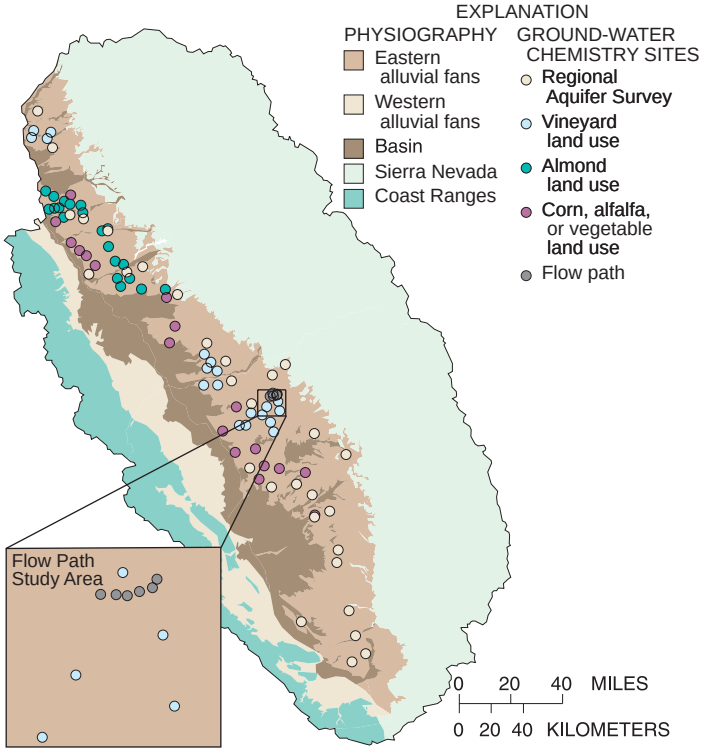
At all levels of study, relevant ancillary information, such as land use, soil and aquifer properties, fertilizer-use rate, and locations of dairies, was collected to help explain the chemical and ecological data. Detailed information, such as change in streamflow during a winter storm or the timing of use of a particular pesticide, was also used for both design and interpretation of specialized studies. In general, the questions addressed by each study component became more focused during each of the 3 years of intensive data collection (September 1992 to August 1995).



Location of stream chemistry sites.



Location of steam ecology sites.



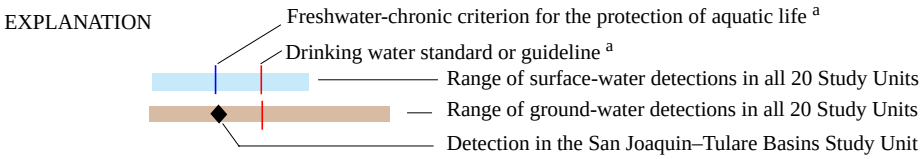
Location of ground-water chemistry sites.

SUMMARY OF DATA COLLECTION IN THE SAN JOAQUIN-TULARE BASINS STUDY UNIT, 1992–95

Study component	What data were collected and Why	Types of sites sampled	Number of sites	Sampling frequency and period
Stream Chemistry				
Basic Fixed Sites (BFS)—general water chemistry	Streamflow, nutrients, major chemical constituents, organic carbon, suspended sediment, water temperature, specific conductance, pH, and dissolved oxygen to describe concentrations and seasonal variations.	Representative of a variety of agricultural land uses, and the basin outflow.	10	Monthly plus storms Jan. 1993–Dec. 1994
Intensive Fixed Sites (IFS)—pesticides	In addition to the above constituents, approximately 83 dissolved pesticides to describe concentrations and seasonal variations.	Subset of basic sites representing contrasting physiographic areas, and the basin outflow.	4	twice weekly to monthly Jan. 1993–Dec. 1993
Synoptic sites—water chemistry	Streamflow, pesticides, water temperature, specific conductance, pH, and dissolved oxygen to describe concentrations and spatial distributions.	Basic sites and others representing agricultural and urban land uses.	23 (low flow)	Once June 1994
Contaminants in bed sediments	Total PCBs, 32 organochlorine pesticides, 63 semivolatile organic compounds, and 44 trace elements to determine occurrence and spatial distribution.	Depositional zones of all basic and intensive sites, plus additional synoptic sites.	17	Once Oct. 1992
Contaminants in aquatic biota	Total PCBs, 30 organochlorine pesticides, and 24 trace elements were analyzed to determine occurrence and spatial distribution. Clams and whole fish for organic contaminants. Clams, fish livers, or crayfish for trace elements.	Same sites as for contaminants in bed sediment where tissue could be collected.	18	Once Oct.–Nov. 1992
Stream Ecology				
Intensive assessments	Assess communities of fish, macroinvertebrates, and algae at each site; and quantitatively describe stream habitat for these organisms.	Subset of BFS (9 of 10) plus a site in Yosemite National Park.	3 4 6	3 reaches/site in 1995 1 reach/year, 1993–95 1 reach in 1993
Synoptic studies	Similar to the above, one reach per site, for areal comparison of habitat and community composition, nutrient samples collected.	Subset of BFS plus others.	32	Once in either 1993 or 1994
Ground-Water Chemistry				
Regional Aquifer Survey—eastern alluvial fans	Major chemical constituents, nutrients, 83 pesticides, 60 volatile organic compounds, and radon to determine occurrence of these constituents in this region.	Domestic wells in the eastern alluvial fans, San Joaquin Valley.	30	Once in 1995
Land-use effects—corn, alfalfa, and vegetable row crops	Major chemical constituents, nutrients, 83 pesticides, 60 volatile organic compounds, and radon to describe the effects of agricultural land use on shallow ground water, eastern alluvial fans.	Shallow domestic wells; Shallow monitoring wells; >50 percent corn, alfalfa, and vegetables grown in rotation within a 0.25-mile radius.	20 10	Once in 1995
Land-use effects—almond orchards	Major chemical constituents, nutrients, 83 pesticides, 60 volatile organic compounds, and radon to describe the effects of agricultural land use on shallow ground water, eastern alluvial fans.	Shallow domestic wells; Shallow monitoring wells; >50 percent almond orchards within 0.25 mile radius.	20 10	Once in 1994
Land-use effects—vineyards	Major chemical constituents, nutrients, 83 pesticides, 60 volatile organic compounds, and radon to describe the effects of agricultural land use on shallow ground water, eastern alluvial fans.	Shallow domestic wells; Shallow monitoring wells; >50 percent vineyards within 0.25-mile radius.	20 10	Once in 1993
Chemical and physical processes along ground-water flow paths	Major chemical constituents, nutrients, 83 pesticides, 60 volatile organic compounds, radon, transformation products of 1,2-dibromo-3-chloropropane, and constituents used to estimate date when ground water was recharged.	20 wells at 6 sites along an approximate ground-water flow path beneath vineyard land use in eastern alluvial fan, San Joaquin Valley.	20	Once in 1994 Once in 1995
Special Studies				
Dissolved pesticide transport in winter storms	Dissolved pesticides and streamflow were measured along with a dye traveltime study to assess the variability of concentrations during storms and the impact on the basin outflow. Specific agricultural and urban areas were assessed.	2 IFS, 3 western valley sites, and basin outflow. 5 eastern valley sites, 3 agricultural drains, and basin outflow. 5 urban sites, 3 agricultural drains, 7 eastern valley sites, and basin outflow.	6 9 16	Jan.–Feb. 1993 Jan.–Feb. 1994 Feb.–Mar. 1995
Transport of sediment-bound pesticides	Sediment-bound pesticides, dissolved pesticide, suspended sediment, and streamflow to compare winter and irrigation season transport.	2 Coast Ranges sites, 2 agricultural drains, 7 western valley sites, and basin outflow.	8 12	June 1994 Jan. 1995
Aquatic ecology—Merced River, Yosemite National Park	Assessment of algal community, chlorophyll-a and ash-free dry mass, and supporting data on nutrients, major constituents, trace elements, and organic contaminants in bed sediment and tissue.	Synoptic sites.	8	Sept. 1995

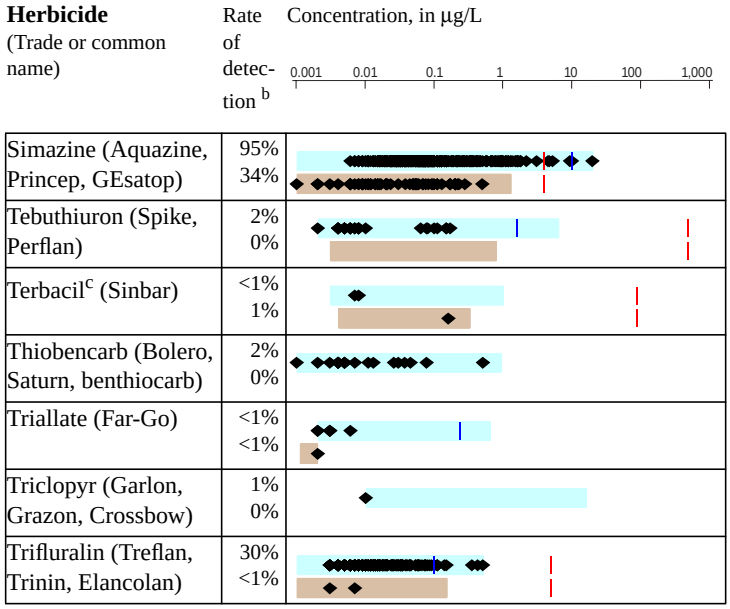
The following tables summarize data collected for NAWQA studies from 1992–95 by showing results for the San Joaquin–Tulare Basins Study Unit compared to the NAWQA national range for each compound detected. The data were collected at a wide variety of places and times. In order to represent the wide concentration ranges observed among Study Units, logarithmic scales are used to emphasize the general magnitude of concentrations (such as 10, 100, or 1000), rather than the precise number. The complete dataset used to construct these tables is available upon request.

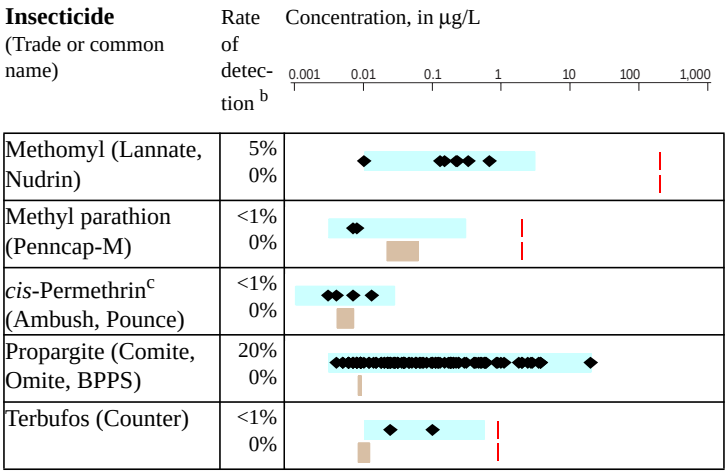
Concentrations of herbicides, insecticides, volatile organic compounds, and nutrients detected in ground and surface waters of the San Joaquin–Tulare Basins Study Unit. [mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; %, percent; <, less than; - -, not measured; trade names may vary]

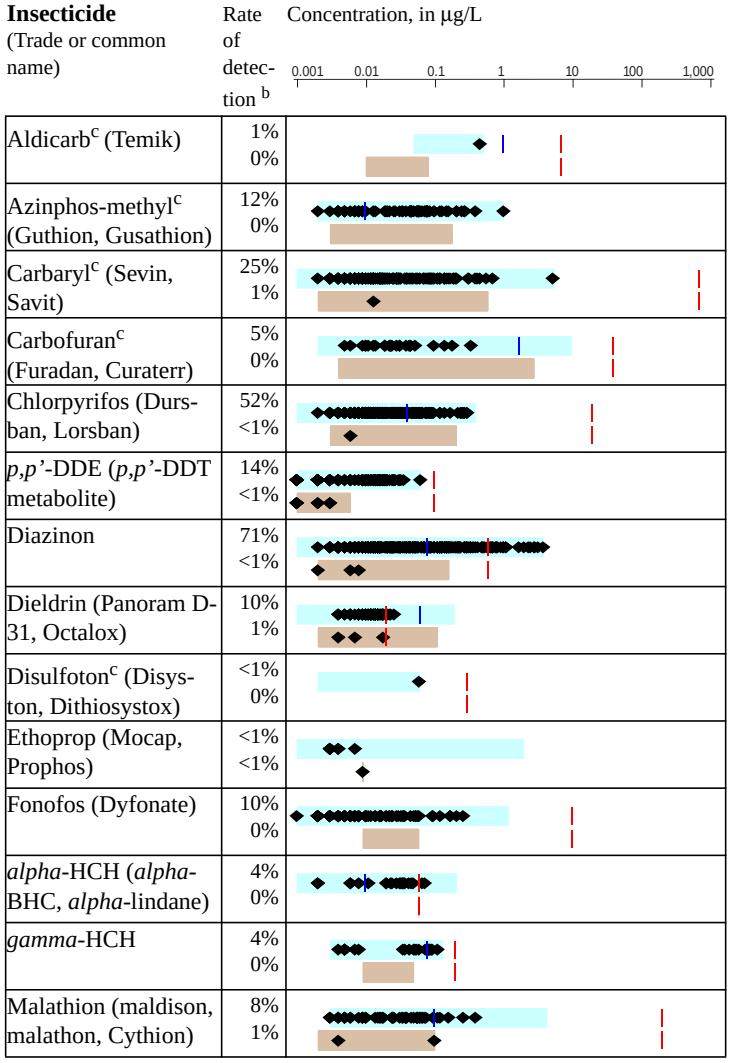


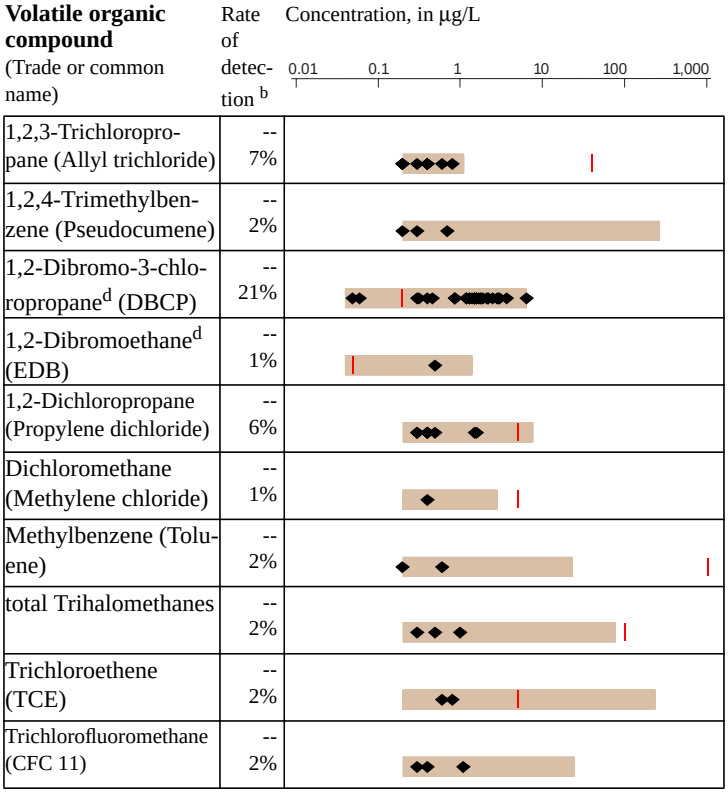
Herbicide (Trade or common name)	Rate of detection [b]	Concentration, in µg/L (0.001, 0.01, 0.1, 1, 10, 100, 1,000)
Alachlor (Lasso)	9% 0%	
2,6-Diethylaniline (Alachlor metabolite)	<1% 0%	
Atrazine (AAtrex, Gesaprim)	27% 7%	
Deethylatrazine[c] (Atrazine metabolite)	<1% 7%	
Benfluralin (Balan, Benefin, Bonalan)	2% 0%	
Bromacil (Hyvar X, Urox B, Bromax)	8% 0%	
Butylate (Sutan, Genate Plus, butilate)	4% <1%	
Cyanazine (Bladex, Fortrol)	34% 1%	
2,4-D (2,4-PA)	12% 0%	
2,4-DB (Butyrac, Embutox)	1% 0%	
DCPA (Dacthal, chlorthal-dimethyl)	22% <1%	
Dichlorprop (2,4-DP, Seritox 50, Kildip)	3% 0%	
Dinoseb (DNBP, DN 289, Premerge)	0% 2%	
Diuron (Karmex, Direx, DCMU)	54% 12%	
EPTC (Eptam)	43% 1%	

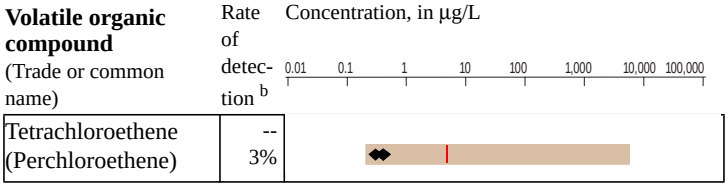
Herbicide (Trade or common name)	Rate of detection [b]	Concentration, in µg/L (0.001, 0.01, 0.1, 1, 10, 100, 1,000)
Ethalfluralin (Sonalan, Sonalen)	13% <1%	
Linuron (Lorox, Linex, Sarclex)	<1% 0%	
MCPA (Agritox, Agroxone)	3% 0%	
Metolachlor (Dual, Pennant)	44% 1%	
Metribuzin (Lexone, Sencor)	3% 0%	
Molinate (Ordram)	9% 0%	
Napropamide (Devrinol)	24% 1%	
Norflurazon (Evital, Solicam, Telok)	8% 2%	
Oryzalin (Surflan, Dirimal, Ryzelan)	8% 0%	
Pebulate (Tillam)	11% 0%	
Pendimethalin (Prowl, Stomp)	4% 0%	
Prometon (Gesagram, prometone)	3% 1%	
Pronamide (Kerb, propyzamid)	3% 0%	
Propachlor (Ramrod, propachlore)	<1% 0%	
Propanil (Stampede, Surcopur)	<1% 0%	


Herbicide
(Trade or common name)
Rate of detection b
Concentration, in µg/L
0.001 0.01 0.1 1 10 100 1,000
Simazine (Aquazine, Princep, GEsatop)
95%
34%
Tebuthiuron (Spike, Perflan)
2%
0%
Terbacil c (Sinbar)
<1%
1%
Thiobencarb (Bolero, Saturn, benthiocarb)
2%
0%
Triallate (Far-Go)
<1%
<1%
Triclopyr (Garlon, Grazon, Crossbow)
1%
0%
Trifluralin (Treflan, Trinin, Elancolan)
30%
<1%


Insecticide
(Trade or common name)
Rate of detection b
Concentration, in µg/L
0.001 0.01 0.1 1 10 100 1,000
Methomyl (Lannate, Nudrin)
5%
0%
Methyl parathion (Penncap-M)
<1%
0%
cis-Permethrin c (Ambush, Pounce)
<1%
0%
Propargite (Comite, Omite, BPPS)
20%
0%
Terbufos (Counter)
<1%
0%


Insecticide
(Trade or common name)
Rate of detection b
Concentration, in µg/L
0.001 0.01 0.1 1 10 100 1,000
Aldicarb c (Temik)
1%
0%
Azinphos-methyl c (Guthion, Gusathion)
12%
0%
Carbaryl c (Sevin, Savit)
25%
1%
Carbofuran c (Furadan, Curaterr)
5%
0%
Chlorpyrifos (Dursban, Lorsban)
52%
<1%
p,p'-DDE (p,p'-DDT metabolite)
14%
<1%
Diazinon
71%
<1%
Dieldrin (Panoram D-31, Octalox)
10%
1%
Disulfoton c (Disyston, Dithiosystox)
<1%
0%
Ethoprop (Mocap, Prophos)
<1%
<1%
Fonofos (Dyfonate)
10%
0%
alpha-HCH (alpha-BHC, alpha-lindane)
4%
0%
gamma-HCH
4%
0%
Malathion (maldison, malathon, Cythion)
8%
1%


Volatile organic compound
(Trade or common name)
Rate of detection b
Concentration, in µg/L
0.01 0.1 1 10 100 1,000
1,2,3-Trichloropropane (Allyl trichloride)
--
7%
1,2,4-Trimethylbenzene (Pseudocumene)
--
2%
1,2-Dibromo-3-chloropropane d (DBCP)
--
21%
1,2-Dibromoethane d (EDB)
--
1%
1,2-Dichloropropane (Propylene dichloride)
--
6%
Dichloromethane (Methylene chloride)
--
1%
Methylbenzene (Toluene)
--
2%
total Trihalomethanes
--
2%
Trichloroethene (TCE)
--
2%
Trichlorofluoromethane (CFC 11)
--
2%


Volatile organic compound
(Trade or common name)
Rate of detection b
Concentration, in µg/L
0.01 0.1 1 10 100 1,000 10,000 100,000
Tetrachloroethene (Perchloroethene)
--
3%

Nutrient (Trade or common name)	Rate of detection [b]	Concentration, in mg/L (0.01, 0.1, 1, 10, 100, 1,000, 10,000, 100,000)
Dissolved ammonia	94% 56%	
Dissolved ammonia plus organic nitrogen as nitrogen	77% 6%	
Dissolved phosphorus as phosphorus	96% 85%	
Dissolved nitrite plus nitrate	95% 97%	

Other	Rate of detection [b]	Concentration, in pCi/L (1, 10, 100, 1,000, 10,000, 100,000)
Radon 222	-- 100%	

Herbicides, insecticides, volatile organic compounds, and nutrients not detected in ground and surface waters of the San Joaquin–Tulare Basins Study Unit.

Herbicides

2,4,5-T

2,4,5-TP (Silvex, Fenoprop)

Acetochlor (Harness Plus, Surpass)

Acifluorfen (Blazer, Tackle 2S)

Bentazon (Basagran, Bentazone, Bendioxide)

Bromoxynil (Buctril, Brominal)

Chloramben (Amiben, Amilon-WP, Vegiben)

Clopyralid (Stinger, Lontrel, Reclaim, Transline)

Dacthal mono-acid (Dacthal metabolite)

Dicamba (Banvel, Dianat, Scotts Proturf)

Fenuron (Fenulon, Fenidim)

Fluometuron (Flo-Met, Cotoran, Cottonex, Meturon)

MCPB (Thistrol)

Neburon (Neburea, Neburyl, Noruben)

Picloram (Grazon, Tordon)

Propham (Tuberite)

Insecticides

3-Hydroxycarbofuran (Carbofuran metabolite)

Aldicarb sulfone (Standak, aldoxycarb, aldicarb metabolite)

Aldicarb sulfoxide (Aldicarb metabolite)

Methiocarb (Slug-Geta, Grandslam, Mesurol)

Oxamyl (Vydate L, Pratt)

Parathion (Roethyl-P, Alkron, Panthion, Phoskil)

Phorate (Thimet, Granutox, Geomet, Rampart)

Propoxur (Baygon, Blattanex, Unden, Proprotox)

Volatile organic compounds

1,1,1,2-Tetrachloroethane (1,1,1,2-TeCA)

1,1,1-Trichloroethane (Methylchloroform)

1,1,2,2-Tetrachloroethane

1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113, CFC 113)

1,1,2-Trichloroethane (Vinyl trichloride)

1,1-Dichloroethane (Ethylidene dichloride)

1,1-Dichloroethene (Vinylidene chloride)

1,1-Dichloropropene

1,2,3-Trichlorobenzene (1,2,3-TCB)

1,2,4-Trichlorobenzene

1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB)

1,2-Dichloroethane (Ethylene dichloride)

1,3,5-Trimethylbenzene (Mesitylene)

1,3-Dichlorobenzene (*m*-Dichlorobenzene)

1,3-Dichloropropane (Trimethylene dichloride)

1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB)

1-Chloro-2-methylbenzene (*o*-Chlorotoluene)

1-Chloro-4-methylbenzene (*p*-Chlorotoluene)

2,2-Dichloropropane

Benzene

Bromobenzene (Phenyl bromide)

Bromochloromethane (Methylene chlorobromide)

Bromomethane (Methyl bromide)

Chlorobenzene (Monochlorobenzene)

Chloroethane (Ethyl chloride)

Chloroethene (Vinyl chloride)

Chloromethane (Methyl chloride)

Dibromomethane (Methylene dibromide)

Dichlorodifluoromethane (CFC 12, Freon 12)

Dimethylbenzenes (Xylenes (total))

Ethenylbenzene (Styrene)

Ethylbenzene (Phenylethane)

Hexachlorobutadiene

Isopropylbenzene (Cumene)

Methyl *tert*-butyl ether[e] (MTBE)

Naphthalene

Tetrachloromethane (Carbon tetrachloride)

cis-1,2-Dichloroethene ((Z)-1,2-Dichloroethene)

cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene)

n-Butylbenzene (1-Phenylbutane)

n-Propylbenzene (Isocumene)

p-Isopropyltoluene (*p*-Cymene)

sec-Butylbenzene

tert-Butylbenzene

trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene)

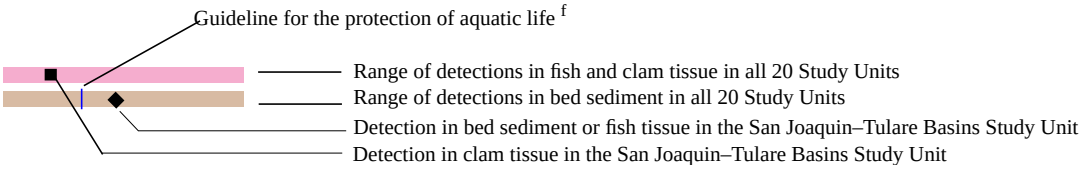
trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene)

Nutrients

No nondetects

Concentrations of semivolatile organic compounds, organochlorine compounds, and trace elements detected in fish and clam tissue and bed sediment of the San Joaquin–Tulare Basins Study Unit. [µg/g, micrograms per gram, in dry weight; µg/kg, micrograms per kilogram, in dry weight for semivolatile organic compounds and organochlorine compounds in bed sediment, and in wet weight for organochlorine compounds in fish and clam tissue; %, percent; <, less than; - -, not measured; trade names may vary]

EXPLANATION

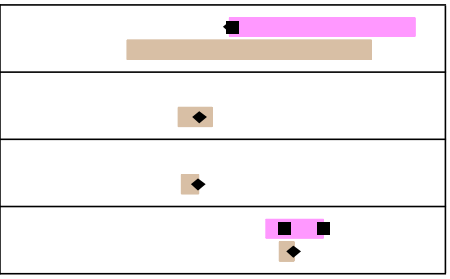


Semivolatile organic compound	Rate of detection b	Concentration, in µg/kg (0.1, 1, 10, 100, 1,000, 10,000, 100,000)
1-Methylphenanthrene	-- 6%	
1-Methylpyrene	-- 6%	
2,6-Dimethylnaphthalene	-- 78%	
2,6-Dinitrotoluene	-- 6%	
2-Methylanthracene	-- 6%	
4,5-Methylenephenanthrene	-- 11%	
9H-Carbazole	-- 6%	
9H-Fluorene	-- 6%	
Acridine	-- 6%	
Anthracene	-- 17%	
Anthraquinone	-- 6%	
Benz[*a*]anthracene	-- 28%	
Benzo[*a*]pyrene	-- 17%	
Benzo[*b*]fluoranthene	-- 33%	
Benzo[*k*]fluoranthene	-- 33%	
Butylbenzylphthalate	-- 28%	
Chrysene	-- 33%	
Di- *n* -butylphthalate	-- 78%	

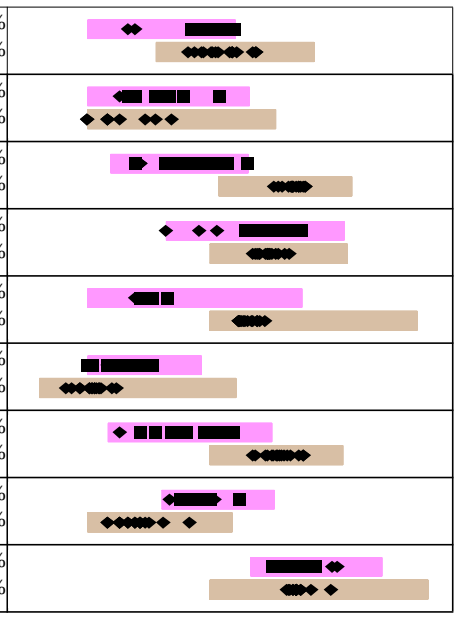
Semivolatile organic compound	Rate of detection b	Concentration, in µg/kg (0.1, 1, 10, 100, 1,000, 10,000, 100,000)
Di- *n* -octylphthalate	-- 6%	
Dibenz[*a,h*]anthracene	-- 6%	
Diethylphthalate	-- 17%	
Fluoranthene	-- 35%	
Indeno[1,2,3- *cd*]pyrene	-- 11%	
Phenanthrene	-- 33%	
Phenol	-- 56%	
Pyrene	-- 35%	
bis(2-Ethylhexyl)phthalate	-- 94%	
p-Cresol	-- 28%	

Organochlorine compound (Trade name)	Rate of detection b	Concentration, in µg/kg (0.01, 0.1, 1, 10, 100, 1,000, 10,000, 100,000)
total-Chlordane	0% 6%	
DCPA (dacthal, chlorthal-dimethyl)	28% 6%	
p,p'-DDE	89% 72%	
total-DDT	89% 72%	
Dieldrin (Panoram D-31, Octalox)	17% 17%	

Organochlorine compound (Trade name)	Rate of detection [b]	Concentration, in µg/kg (0.01, 0.1, 1, 10, 100, 1,000, 10,000, 100,000)
PCB, total	11% 0%	
cis-Permethrin (Ambush, Pounce)	-- 6%	
trans-Permethrin (Ambush, Pounce)	-- 6%	
Toxaphene (camphechlor)	11% 6%	



Trace element	Rate of detection [b]	Concentration, in µg/g (0.01, 0.1, 1, 10, 100, 1,000, 10,000)
Arsenic	94% 100%	
Cadmium	62% 56%	
Chromium	94% 100%	
Copper	100% 100%	
Lead	38% 100%	
Mercury	69% 100%	
Nickel	88% 100%	
Selenium	75% 100%	
Zinc	100% 100%	



Semivolatile organic compounds, organochlorine compounds, and trace elements not detected in fish and clam tissue and bed sediment of the San Joaquin–Tulare Basins Study Unit.

Semivolatile organic compounds

1,2,4-Trichlorobenzene

1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB)

1,2-Dimethylnaphthalene

1,3-Dichlorobenzene (*m*-Dichlorobenzene)

1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB)

1,6-Dimethylnaphthalene

1-Methyl-9H-fluorene

2,2-Biquinoline

2,3,6-Trimethylnaphthalene

2,4-Dinitrotoluene

2-Chloronaphthalene

2-Chlorophenol

2-Ethylnaphthalene

3,5-Dimethylphenol

4-Bromophenyl-phenylether

4-Chloro-3-methylphenol

4-Chlorophenyl-phenylether

Acenaphthene

Acenaphthylene

Azobenzene

Benzo [*c*] cinnoline

Benzo [*g,h,i*] perylene

C8-Alkylphenol

Dibenzothiophene

Dimethylphthalate

Isophorone

Isoquinoline

N-Nitrosodi-*n*-propylamine

N-Nitrosodiphenylamine

Naphthalene

Nitrobenzene

Pentachloronitrobenzene

Phenanthridine

Quinoline

bis (2-Chloroethoxy)methane

Organochlorine compounds

Aldrin (HHDN, Octalene)

Chloroneb (chloronebe, Demosan, Soil Fungicide 1823)

Endosulfan I (*alpha*-Endosulfan, Thiodan, Cyclodan, Beosit, Malix, Thimul, Thifor)

Endrin (Endrine)

Heptachlor epoxide (Heptachlor metabolite)

Heptachlor (Heptachlore, Velsicol 104)

Hexachlorobenzene (HCB)

Isodrin (Isodrine, Compound 711)

Mirex (Dechlorane)

Pentachloroanisole (PCA, pentachlorophenol metabolite)

alpha-HCH (*alpha*-BHC, *alpha*-lindane, *alpha*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

beta-HCH (*beta*-BHC, *beta*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

delta-HCH (*delta*-BHC, *delta*-hexachlorocyclohexane, *delta*-benzene hexachloride)

gamma-HCH (Lindane, *gamma*-BHC, Gammexane, Gexane, Soprocide, *gamma*-hexachlorocyclohexane, *gamma*-benzene hexachloride, *gamma*-benzene)

o,p'-Methoxychlor

p,p'-Methoxychlor (Marlate, methoxychlore)

Trace elements

No nondetects

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[a] Selected water-quality standards and guidelines (Gilliom and others, in press).

[b] Rates of detection are based on the number of analyses and detections in the Study Unit, not on national data. Rates of detection for herbicides and insecticides were computed by only counting detections equal to or greater than 0.01 µg/L in order to facilitate equal comparisons among compounds, which had widely varying detection limits. For herbicides and insecticides, a detection rate of "<1%" means that all detections are less than 0.01 µg/L, or the detection rate rounds to less than one percent. For other compound groups, all detections were counted and minimum detection limits for most compounds were similar to the lower end of the national ranges shown. Method detection limits for all compounds in these tables are summarized in (Gilliom and others, in press).

[c] Detections of these compounds are reliable, but concentrations are determined with greater uncertainty than for the other compounds and are reported as estimated values (Zaugg and others, 1995).

[d] In the San Joaquin–Tulare Basins Study Unit, 152 ground-water samples were analyzed for 1,2-dibromo-3-chloropropane (DBCP) and 1,2-dibromoethane (EDB) at lower detection limits (0.03 and 0.04 µg/L, respectively). DBCP was detected in 50 of these samples and EDB was detected in one sample.

e The guideline for methyl *tert*-butyl ether is between 20 and 40 µg/L; if the tentative cancer classification C is accepted, the lifetime health advisory will be 20 µg/L (Gilliom and others, in press).

[f] Selected sediment-quality guidelines (Gilliom and others, in press).

(*These tables were designed and built by Sarah Ryker, Jonathan Scott, and Alan Haggland*.)

Brown, R.L., 1975, The occurrence and removal of nitrogen in subsurface agricultural drainage from the San Joaquin Valley, California: Water Research, v. 9, no. 5/6, p. 529–546.

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The terms in this glossary were compiled from numerous sources. Some definitions have been modified and may not be the only valid ones for these terms.

Algae—chlorophyll-bearing non-vascular, primarily aquatic species that have no true roots, stems, or leaves; most algae are microscopic, but some species can be as large as vascular plants.

Alluvial aquifer—A water-bearing deposit of unconsolidated material (sand and gravel) left behind by a river or other flowing water.

Alluvium—Deposits of clay, silt, sand, gravel or other particulate rock material left by a river in a streambed, on a flood plain, delta, or at the base of a mountain.

Ammonia—A compound of nitro-gen and hydrogen (NH_3) that is a common byproduct of animal waste. Ammonia readily converts to nitrate in soils and streams.

Anomalies—As related to fish, externally visible skin or subcu-taneous disorders, including deformities, eroded fins, lesions, and tumors.

Aquatic life criteria—Water-quality guidelines for protection of aquatic life. Often refers to U.S. Environmental Protection Agency water-quality criteria for protec-tion of aquatic organisms. *See* Water-quality guidelines, Water-quality criteria, and Freshwater chronic criteria.

Aquifer—A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Background concentration—A concentration of a substance in a particular environment that is indicative of minimal influence by human (anthropogenic) sources.

Base flow—Sustained, low flow in a stream; ground-water discharge is the source of base flow in most places.

Basic Fixed Sites—Sites on streams at which streamflow is measured and samples are col-lected for temperature, salinity, suspended sediment, major ions and metals, nutrients, and organic carbon to assess the broad-scale spatial and temporal character and transport of inorganic constituents of stream water in relation to hydrologic conditions and environmental settings.

Basin—*See* Drainage basin.

Bed sediment—The material that temporarily is stationary in the bottom of a stream or other watercourse.

Bed sediment and tissue studies—Assessment of concentra-tions and distributions of trace elements and hydrophobic organic contaminants in streambed sedi-ment and tissues of aquatic organ-isms to identify potential sources and to assess spatial distribution.

Benthic invertebrates—Insects, mollusks, crustaceans, worms, and other organisms without a back-bone that live in, on, or near the bottom of lakes, streams, or oceans.

Biota—Living organisms.

Chlordane—Octachloro-4,7-methanotetrahydroindane. An organochlorine insecticide no longer registered for use in the United States. Technical chlordane is a mixture in which the primary components are *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, and heptachlor.

Chlorofluorocarbons—A class of volatile compounds consisting of carbon, chlorine, and fluorine. Commonly called freons, which have been used in refrigeration mechanisms, as blowing agents in the fabrication of flexible and rigid foams, and, until several years ago, as propellants in spray cans.

Community—In ecology, the species that interact in a common area.

Concentration—The amount or mass of a substance present in a given volume or mass of sample. Usually expressed as micrograms per liter (water sample) or micro- grams per kilogram (sediment or tissue sample).

Confluence—The flowing together of two or more streams; the place where a tributary joins the main stream.

Contamination—Degradation of water quality compared to original or natural conditions due to human activity.

Criterion—A standard rule or test on which a judgment or decision can be based.

Cubic foot per second—(ft^3/s, or cfs) is the rate of water discharge representing a volume of a 1 cubic foot passing a given point during 1 second, equivalent to approxi-mately 7.48 gallons per second or 448.8 gallons per minute or 0.02832 cubic meter per second.

Degradation products—Com-pounds resulting from trans-formation of an organic substance through chemical, photochemical, and(or) biochemical reactions.

Denitrification—A process by which oxidized forms of nitrogen such as nitrate (NO_3^-) are reduced to form nitrites, nitrogen oxides, ammonia, or free nitrogen: com-monly brought about by the action of denitrifying bacteria and usually resulting in the escape of nitrogen to the air.

Detection limit—The concentra-tion below which a particular analytical method cannot deter-mine, with a high degree of certainty, a concentration.

DDT—dichloro-diphenyl-trichloro-ethane. An organochlorine insect-icide no longer registered for use in the United States.

Dieldrin—An organochlorine insecticide no longer registered for use in the United States. Also a degradation product of the insecticide aldrin.

Discharge—Rate of fluid flow passing a given point at a given moment in time, expressed as volume per unit of time.

Dissolved solids—Amount of minerals, such as salt, that are dissolved in water; amount of dissolved solids is an indicator of salinity or hardness.

Drainage basin—The portion of the surface of the Earth that con-tributes water to a stream through overland runoff, including tributaries and impoundments.

Drinking-water standard or guideline—A threshold concen-tration in a public drinking-water supply, designed to protect human health. As defined here, standards are U.S. Environmental Protection Agency regulations that specify the maximum contamination levels for public water systems required to protect the public welfare; guide-lines have no regulatory status and are issued in an advisory capacity.

Ecological studies—Studies of biological communities and habitat characteristics to evaluate the effects of physical and chemical characteristics of water and hydro-logic conditions on aquatic biota and to determine how biological and habitat characteristics differ among environmental settings in NAWQA Study Units.

Ecoregion—An area of similar climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

Ecosystem—The interacting popu-lations of plants, animals, and microorganisms occupying an area, plus their physical environment.

Effluent—Outflow from a partic-ular source, such as a stream that flows from a lake or liquid waste that flows from a factory or sewage-treatment plant.

Environmental setting—Land area characterized by a unique combi-nation of natural and human-related factors, such as row-crop cultivation or glacial-till soils.

Ephemeral stream—A stream or part of a stream that flows only in direct response to precipitation or snowmelt. Its channel is above the water table at all times.

Erosion—The process whereby materials of the Earth's crust are loosened, dissolved, or worn away and simultaneously moved from one place to another.

Eutrophication—The process by which water becomes enriched with plant nutrients, most com-monly phosphorus and nitrogen.

Fertilizer—Any of a large number of natural or synthetic materials, including manure and nitrogen, phosphorus, and potassium com-pounds, spread on or worked into soil to increase its fertility.

Fish community—*See* Community.

Flow path—An underground route for ground-water movement, extending from a recharge (intake) zone to a discharge (output) zone such as a shallow stream.

Freshwater chronic criteria—The highest concentration of a contami-nant that freshwater aquatic organisms can be exposed to for an extended period of time (4 days) without adverse effects. *See* Water-quality criteria.

Fumigant—A substance or mix-ture of substances that produce gas, vapor, fume, or smoke intended to destroy insects, bacteria, or rodents.

Ground water—In general, any water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations.

Habitat—The part of the physical environment where plants and animals live.

Herbicide—A chemical or other agent applied for the purpose of killing undesirable plants. *See also* Pesticide.

Hydrograph—Graph showing variation of water elevation, velo-city, streamflow, or other property of water with respect to time.

Insecticide—A substance or mix-ture of substances intended to destroy or repel insects.

Intensive Fixed Sites—Basic Fixed Sites with increased sampling fre-quency during selected seasonal periods and analysis of dissolved pesticides for 1 year. Most NAWQA Study Units have one to two integrator Intensive Fixed Sites and one to four indicator Intensive Fixed Sites.

Invertebrate—An animal having no backbone or spinal column. *See also* Benthic invertebrates.

Irrigation return flow—The part of irrigation applied to the surface that is not consumed by evapotranspiration or uptake by plants and that migrates to an aquifer or surface-water body.

Land-use study—A network of existing shallow wells in an area having a relatively uniform land use. These studies are a subset of the Study-Unit Survey and have the goal of relating the quality of shallow ground water to land use. *See* Study-Unit Survey.

Leaching—The removal of materials in solution from soil or rock to ground water; refers to movement of pesticides or nutrients from land surface to ground water.

Load—General term that refers to a material or constituent in solu-tion, suspension, or in transport; usually expressed in terms of mass or volume.

Main stem—The principal course of a river or a stream.

Maximum contaminant level (MCL)—Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCL's are enforceable standards established by the U.S. Environmental Protection Agency.

Mean—The average of a set of observations, unless otherwise specified.

Mean discharge (MEAN)—The arithmetic mean of individual daily mean discharges during a specific period, usually daily, monthly, or annually.

Median—The middle or central value in a distribution of data ranked in order of magnitude. The median is also known as the 50th percentile.

Metabolite—A substance pro-duced in or by biological processes.

Method detection limit—The minimum concentration of a sub-stance that can be accurately ident-ified and measured with present laboratory technologies.

Micrograms per liter (µg/L)—A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to one part per billion in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Milligrams per liter (mg/L)—A unit expressing the concentration of chemical constituents in solu-tion as weight (milligrams) of solute per unit volume (liter) of water; equivalent to one part per million in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Monitoring well—A well designed for measuring water levels and testing ground-water quality.

Mouth—The place where a stream discharges to a larger stream, a lake, or the sea.

Nitrate—An ion consisting of nitrogen and oxygen (NO_3^-). Nitrate is a plant nutrient and is very mobile in soils.

Nonpoint source—A pollution source that cannot be defined as originating from discrete points such as pipe discharge. Areas of fertilizer and pesticide applications, atmospheric deposition, manure, and natural inputs from plants and trees are types of nonpoint source pollution.

Nutrient—Element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phos-phorus, and potassium.

Organochlorine compound—Synthetic organic compounds containing chlorine. As generally used, term refers to compounds containing mostly or exclusively carbon, hydrogen, and chlorine. Examples include organo-chlorine insecticides, polychlor-inated biphenyls, and some solvents containing chlorine.

Organochlorine insecticide—A class of organic insecticides con-taining a high percentage of chlorine. Includes dichlorodi-phenylethanes (such as DDT), chlorinated cyclodienes (such as chlordane), and chlorinated ben-zenes (such as lindane). Most organochlorine insecticides were banned because of their carcino-genicity, tendency to bioaccu-mulate, and toxicity to wildlife.

Organophosphate insecticides—A class of insecticides derived from phosphoric acid. They tend to have high acute toxicity to verte-brates. Although readily metab-olized by vertebrates, some metabolic products are more toxic than the parent compound.

Pesticide—A chemical applied to crops, rights of way, lawns or residences to control weeds, insects, fungi, nematodes, rodents or other "pests."

Phosphorus—A nutrient essential for growth that can play a key role in stimulating aquatic growth in lakes and streams.

Precipitation—Any or all forms of water particles that fall from the atmosphere, such as rain, snow, hail, and sleet.

Radon—A naturally occurring, colorless, odorless, radioactive gas formed by the disintegration of the element radium; damaging to human lungs when inhaled.

Recharge—Water that infiltrates the ground and reaches the saturated zone.

Relative abundance—The number of organisms of a particular kind present in a sample relative to the total number of organisms in the sample.

Riparian—Areas adjacent to rivers and streams with a high density, diversity, and productivity of plant and animal species relative to nearby uplands.

Runoff—Excess rainwater or snow-melt that is transported to streams by overland flow, tile drains, or ground water.

Sediment—Particles, derived from rocks or biological materials, that have been transported by a fluid or other natural process, sus-pended or settled in water.

Semivolatile organic compound (SVOC)—Operationally defined as a group of synthetic organic com-pounds that are solvent-extractable and can be determined by gas chromatography/mass spectrometry. SVOCs include phenols, phthalates, and polycyclic aromatic hydrocarbons (PAH).

Species—Populations of orga-nisms that may interbreed and pro-duce fertile offspring having simi-lar structure, habits, and functions.

Specific conductance—A measure of the ability of a liquid to conduct an electrical current.

Streamflow—A type of channel flow, applied to that part of sur-face runoff in a stream whether or not it is affected by diversion or regulation.

Stream reach—A continuous part of a stream between two specified points.

Study Unit—A major hydrologic system of the United States in which NAWQA studies are focused. Study Units are geograph-ically defined by a combination of ground- and surface-water features and generally encompass more than 4,000 square miles of land area.

Study Unit Survey—Broad assessment of the water-quality conditions of the major aquifer systems of each Study Unit. The Study-Unit Survey relies primarily on sampling existing wells and, wherever possible, on existing data collected by other agencies and programs. Typically, 20 to 30 wells are sampled in each of three to five aquifer subunits.

Subsurface drain—A shallow drain installed in an irrigated field to intercept the rising ground-water level and maintain the water table at an acceptable depth below the land surface.

Surface water—An open body of water, such as a lake, river, or stream.

Suspended (as used in tables of chemical analyses)**—**The amount (concentration) of undissolved material in a water-sediment mix-ture. It is associated with the material retained on a 0.45-micro-meter filter.

Suspended sediment—Particles of rock, sand, soil, and organic detritus carried in suspension in the water column, in contrast to sediment that moves on or near the streambed.

Suspended-sediment concentration—The velocity-weighted concentration of suspended sediment in the sampled zone (from the water surface to a point approximately 0.3 foot above the bed) expressed as milligrams of dry sediment per liter of water-sediment mixture (mg/L).

Synoptic sites—Sites sampled during a short-term investigation of specific water-quality conditions during selected seasonal or hydro-logic conditions to provide improved spatial resolution for critical water-quality conditions.

Total DDT—The sum of DDT and its metabolites (breakdown products), including DDD and DDE.

Trace element—An element found in only minor amounts (concen-trations less than 1.0 milligram per liter) in water or sediment; includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Urban Site—A site that has greater than 50 percent urbanized and less than 25 percent agricul- tural area.

Volatile organic compounds (VOC)—Organic chemicals that have a high vapor pressure relative to their water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by-products of chlorine disinfection.

Water-quality criteria—Specific levels of water quality which, if reached, are expected to render a body of water unsuitable for its designated use. Commonly refers to water-quality criteria estab-lished by the U.S. Environmental Protection Agency. Water-quality criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish produc-tion, or industrial processes.

Water-quality guidelines—Specific levels of water quality which, if reached, may adversely affect human health or aquatic life. These are nonenforceable guide-lines issued by a governmental agency or other institution.

Water-quality standards—State-adopted and U.S. Environmental Protection Agency-approved ambi-ent standards for water bodies. Standards include the use of the water body and the water-quality criteria that must be met to protect the designated use or uses.

Watershed—*See* Drainage basin.

Water table—The point below the land surface where ground water is first encountered and below which the earth is saturated. Depth to the water table varies widely across the country.

Water year—The continuous 12-month period, October 1 through September 30, in U.S. Geological Survey reports dealing with the surface-water supply. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as the "1980" water year.

Wetlands—Ecosystems whose soil is saturated for long periods seasonally or continuously, including marshes, swamps, and ephemeral ponds.

Withdrawal—The act or process of removing; such as removing water from a stream for irrigation or public water supply.

NAWQA

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