CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

TOTAL MAXIMUM DAILY LOAD (TMDL) REPORT FOR THE PESTICIDES DIAZINON & CHLORPYRIFOS IN:

ARCADE CREEK, ELDER CREEK, ELK GROVE CREEK, MORRISON CREEK, CHICKEN RANCH SLOUGH, AND STRONG RANCH SLOUGH

SACRAMENTO COUNTY, CALIFORNIA

September 2004

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DISCLAIMER

This report by staff of the California Regional Water Quality Control Board, Central Valley Region presents technical information in support of Resolution R5-2004-0109 (Establishment of Total Maximum Daily Loads Of Diazinon and Chlorpyrifos in Sacramento Area Urban Creeks). Mention of specific products does not represent endorsement of those products by the Regional Board.

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September 2004

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LIST of Acronyms and Abbreviations

§	Section (as in a law or regulation)
σg/L	Micrograms/liter (1 σg/L = 1,000 ng/L)
303(d) List	List of waterbodies that are not attaining water quality standards.
Basin Plan	Water Quality Control Plan (Basin Plan) Central Valley Region; Sacramento River and San Joaquin River
BDL	Below detection limit
CALFED	The CALFED Bay Delta Program
CDFG	California Department of Fish and Game
CDPR	California Department of Pesticide Regulation
C. dubia	*Ceriodaphnia dubia* (a zooplankton, specifically a cladoceran)
CFR	The Code of Federal Regulations
cfs	Cubic Feet per Second, a measure of flow
CVRWQCB	Central Valley Regional Water Quality Control Board
CWA	Federal Clean Water Act
CWC	California Water Code
CDFG	California Department of Fish and Game
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
g/d	Grams/day
g/L	Grams/Liter
hydrologic unit/hu	A number assigned to a waterbody based on its location
IRED	Interim Reregistration Eligibility Decision, by the USEPA
lbs/Lbs	Pounds
NCDC	National Climatic Data Center
NPDES	National Pollutant Discharge Elimination System, a Permitting Program
OP Pesticides	Organophosphorus pesticides, including the insecticides Diazinon and Chlorpyrifos
PCOs	Professional pest control operators
Porter-Cologne Act	Porter-Cologne Water Quality Control Act as amended
PUR	Pesticide Use Report - by the California Department of Pesticide Regulation
Regional Board	California Regional Water Quality Control Board-Central Valley Region
TIE	Toxicity Identification Evaluation
TMDL	Total Maximum Daily Load
UCD/ UCDavis	University of California, Davis
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQO	Water Quality Objective

1. INTRODUCTION

1.1 Scope of this Report

Diazinon and chlorpyrifos are broad-spectrum organophosphorus (OP) pesticides used for urban and agricultural pest control in the Sacramento Valley. The scope of this report addresses diazinon- and/or chlorpyrifos-induced impairments of four waterways tributary to the Sacramento River - Arcade Creek, Elder Creek, Elk Grove Creek, Morrison Creek - and two waterways tributary to the American River - Chicken Ranch Slough and Strong Ranch Slough. All six waterways are listed on California's 2002 303(d) List as impaired by elevated diazinon and/or chlorpyrifos concentrations. This report contains the following elements:

- a summary of the regulatory framework (Section 1.2);
- a problem statement that identifies the context, background, and the nature of the impairment (Section 2);
- numerical water quality targets (Section 2.3);
- identification and quantification of sources and source loads (Section 3);
- a linkage analysis between the water quality targets and amount or load of contaminant(s) (Section 4);
- allocation of the necessary load reductions to the various sources and to a margin of safety that takes into account uncertainties and consideration of seasonal variations (Section 5); and
- an implementation plan (Section 6).

1.2 Regulatory Background

Water quality standards are enforced under the federal Clean Water Act and the California Porter-Cologne Water Quality Control Act, and consist of designated beneficial use(s) and water quality criteria or objectives designed to protect such uses. This report was prepared by staff from the California Regional Water Quality Control Board, Central Valley Region (Regional Board) and will be adopted by the Regional Board prior to submittal to the U.S. Environmental Protection Agency (USEPA).

<u>Clean Water Act Section 303(d)</u>

Section 303(d) of the federal Clean Water Act (CWA) requires States to: 1) identify those waters not attaining water quality standards (referred to as the "303(d) list"); 2) set priorities for addressing the identified pollution problems; and 3) establish a "Total Maximum Daily Load" (TMDL) for each identified water body and pollutant to attain water quality standards (the purpose of this report). The State is required to incorporate TMDLs into the State Water Quality Management Plan (40 CFR 130.6(c)(1), 130.7). The California Regional Water Quality Control Board-Central Valley Region: Sacramento River and San Joaquin River Basins Water Quality Control Plan (Basin Plan), and other applicable statewide plans, serve as the State Water Quality Management Plan that governs impaired watersheds in the Sacramento and San Joaquin River basins. TMDLs will be reviewed by the USEPA to determine whether all TMDL requirements are met.

When approved by the USEPA, the TMDL is then applicable (CWA, Section 303(d); USEPA, 2000a).

A TMDL represents the maximum load expressed in terms of mass per time, toxicity or other appropriate measure of a pollutant that a water body can receive and still meet water quality standards (40 CFR130.2(C)i).

Porter-Cologne Water Quality Control Act

The Porter-Cologne Water Quality Control Act, which is contained in Division 7 of the California Water Code (CWC), establishes the responsibilities and authorities of each Regional Water Quality Control Board, including responsibility and authority for regional water quality control and planning. The Central Valley Regional Board establishes water quality objectives (WQOs) and programs to implement the WQOs by amending the Basin Plan for the Sacramento River and San Joaquin River basins. The Regional Board also regulates discharge through Waste Discharge Requirements (WDRs), waivers of WDRs, and prohibitions of discharge.

FIFRA

Since 2001, the USEPA has mandated diazinon and chlorpyrifos use cancellations (phase-outs) and restrictions for urban and agricultural uses (USEPA Diazinon and Chlorpyrifos Interim Reregistration Eligibility Decisions (IREDs)). The USEPA has undertaken the reregistration process for diazinon and chlorpyrifos to ensure that the pesticides meet the safety standards under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Food Quality Protection Act of 1996. Under the IREDs, outdoor urban residential and commercial uses of diazinon will be eliminated. Most urban uses of chlorpyrifos will either be eliminated or severely restricted. Many of the other proposed diazinon and chlorpyrifos use restrictions and cancellations apply to agricultural uses. Substantial reduction of chlorpyrifos use in the urban environment and total elimination of diazinon use in the urban environment are expected to facilitate diazinon and chlorpyrifos concentration reductions in impaired Sacramento County urban waterways. At the time of publication of this TMDL, the IREDS for specific agricultural sites of use are in a public review and comment period. The final USEPA-approved agricultural sites of use may change the estimated future uses summarized in Tables A-3 and A-4.

2. PROBLEM STATEMENT

This Problem Statement:

- summarizes the environmental characteristics of each impaired Sacramento County urban waterway;
- describes the applicable water quality standards (beneficial uses and water quality objectives [WQOs]) as specified in the Basin Plan;
- describes the numeric targets used to meet the WQOs;
- discusses the sources and effects of diazinon and chlorpyrifos in Sacramento County urban waterways; and,

∉# summarizes the monitoring data that indicates the extent of diazinon and chlorpyrifos impairment.

2.1 Environmental Characteristics of Impaired Waterways in Sacramento County

The Sacramento Valley generally has mild winters with precipitation mainly occurring from October to April and little to no precipitation occurring from July to September. Precipitation is usually in the form of rain, although hail and snow have occurred on an irregular basis. The average annual rainfall in the city of Sacramento is 18 inches (NCDC, 1990- 2000). All six impaired urban waterways respond to seasonal rainfall by rapidly, but temporarily, increasing flow.

Table 2-1 lists the six impaired urban waterways and provides information on the extent of impairment in each. Figure 2-1 illustrates the locations of the six impaired waterways. Environmental characteristics of each impaired waterway are described below.

Table 2-1. Sacramento County Urban Waterways on California's 2002 Clean Water Act Section 303(d) List

Waterway Name	Hydrologic Unit	Total Stream Length	Portion Affected	Pollutants/Stressors Causing Impairment
Arcade Creek	519.21	10 miles	10 miles	Diazinon and Chlorpyrifos
Chicken Ranch Slough	519.21	5 miles	5 miles	Diazinon and Chlorpyrifos
Elder Creek	519.12	10 miles	10 miles	Diazinon and Chlorpyrifos
Elk Grove Creek	519.11	5 miles	5 miles	Diazinon
Morrison Creek	519.12	20 miles	20 miles	Diazinon
Strong Ranch Slough	519.21	5 miles	5 miles	Diazinon and Chlorpyrifos

2.1.1 Arcade Creek

Arcade Creek, the most extensively studied waterway in Sacramento County, has a watershed of approximately 40 square miles with elevations ranging from 20 to 270 feet above sea level. The entire watershed lies within urbanized parts of Sacramento County and extends from the northeastern corner of the city of Citrus Heights to the Natomas East Main Drainage Canal (NEMDC). Arcade Creek flows from the northeast to the southwest through low- and high-density residential developments, commercial developments, two major branches of Highway 80, three large golf courses, and three cemeteries, and joins the NEMDC before it flows into the Sacramento River. A major mall and the California Exposition Center (Cal Expo) and horse track are also located within the Arcade Creek watershed.

Arcade Creek is a perennial natural stream with riparian woodlands along the banks from its headwaters to approximately 3 miles upstream of the NEMDC, and is a concrete-lined channel with fewer trees downstream (Russick, 2001). Arcade Creek is dominated by urban runoff with flows that can exceed 2,200 cfs at Watt Avenue within a few hours of storm events due to the existence of a substantial amount of impervious surfaces in the

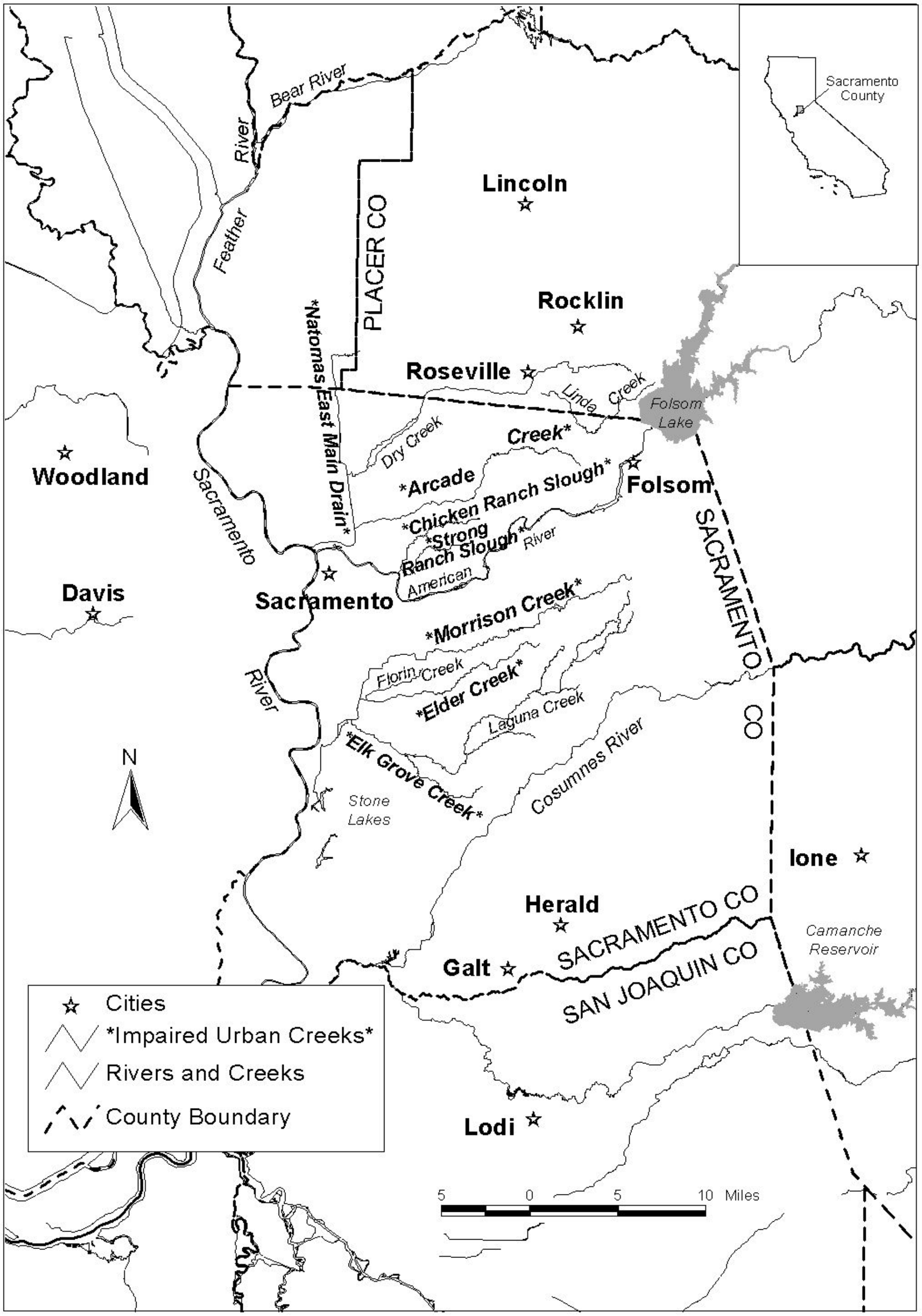


Figure 2-1. Impaired Waterbodies in the Sacramento County Area

watershed that impede infiltration of rainfall. During dry weather, flow in Arcade Creek is very low, averaging 0.5 cfs (Denton, 2001).

2.1.2 Chicken Ranch Slough

Chicken Ranch Slough is a small urban creek with a watershed of approximately six square miles. It begins near the intersection of Whitney Avenue and Eastern Avenue and flows generally southwestward to the American River (DeLorme, 1998). Chicken Ranch Slough and Strong Ranch Slough join just before entering the lower American River near Cal Expo. Except for Del Paso Country Club and several city parks, land use is almost entirely residential and commercial.

2.1.3 Elder Creek

The Elder Creek watershed covers approximately 22 square miles. Elder Creek originates south of Mather Field and Kiefer Boulevard (north of Highway 16) and west of Eagles Nest Road. Elder Creek flows southwestward toward the city of Florin, joining Morrison Creek northwest of the Franklin Boulevard and Mack Road intersection (DeLorme, 1998). Elder Creek has two small tributaries, Florin Creek and Gerber Creek. The eastern portion of the Elder Creek watershed is predominantly rural and the western portion is predominantly urban, where principal land uses include residential, industrial, commercial, grazing, and agriculture. A large commercial nursery is located within the Elder Creek watershed.

2.1.4 Elk Grove Creek

The Elk Grove Creek watershed covers approximately six square miles. Elk Grove Creek begins east of the Grant Line Road and Elk Grove Boulevard intersection and flows northwestward through the city of Elk Grove to join Laguna Creek. From the headwaters of the Elk Grove Creek watershed, land use changes from predominantly rural (grazing, agricultural, and residential) to predominantly urban (residential and commercial in the city of Elk Grove) and back to rural before Elk Grove Creek joins Laguna Creek (DeLorme, 1998).

2.1.5 Morrison Creek

The Morrison Creek watershed covers approximately 150 square miles. Elder Creek, Laguna Creek, and Elk Grove Creek are tributaries to Morrison Creek. Land use in the Morrison Creek watershed is a mix of rural and urban uses including grazing, agricultural, low- to high-density residential, industrial, and commercial. The portion of the watershed east of Hedge Road and Waterman Road is predominantly rural. The portion of the watershed west of these roads is predominantly urban. Morrison Creek flows southwestward from near the intersection of White Rock Road and Grant Line Road to Stone Lake west of Interstate 5 (DeLorme, 1998).

Limited stream flow data exists for Morrison Creek and two of its tributaries, Elder Creek and Elk Grove Creek. Generally, these creeks are perennial with some channelized sections. They experience flashy flow conditions during storm events with much lower flow conditions during dry weather. For example, flows measured in Morrison Creek (and in Florin Creek, a tributary to Elder Creek) increased by two orders of magnitude (ranging from 0.1cfs to 54 cfs) during a two-day storm event monitored by the Regional Board staff in February 2001 (Spector and Harader, 2001).

2.1.6 Strong Ranch Slough

The Strong Ranch Slough watershed covers an area of approximately seven square miles. Strong Ranch Slough is a concrete channel with its origins at the western edge of the city of Carmichael. It flows westward through Arden Oaks and eventually joins Chicken Ranch Slough, which in turn discharges into the American River upstream of Cal Expo. Land use surrounding Strong Ranch Slough is predominantly residential and commercial.

2.2 Water Quality Standards for Impaired Sacramento County Urban Waterways

Water quality standards consist of beneficial uses and Water Quality Objectives (WQOs), as defined in the Basin Plan. The Basin Plan lists (designates) beneficial uses applicable to major waterways located within the Central Valley. Not every surface water body is listed in the Basin Plan; therefore, not every surface water body within the basin has designated beneficial uses. The Basin Plan states, "The beneficial uses of any specifically identified water body generally apply to its tributary streams."

To establish uses in tributary streams, an evaluation would need to be conducted to determine specific beneficial uses and the Basin Plan would need to be amended to establish uses that differ from the downstream waters. The Basin Plan does not specifically identify the six impaired Sacramento County urban waterways addressed by this TMDL. These waterways are, therefore, assumed to have the same beneficial uses as the waters to which they are tributary (i.e., the Sacramento and American Rivers). These uses include Warm and Cold Freshwater Habitat (WARM and COLD, respectively).

The water quality objectives that apply to protect WARM and COLD beneficial uses of the impaired urban waterways are the narrative water quality objectives for pesticides and toxicity. The narrative pesticide objectives state, in part:

- No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses,
- Discharges shall not result in pesticide concentrations in bottom sediments or aquatic life that adversely affect beneficial uses,
- Pesticide concentrations shall not exceed those allowable by applicable antidegradation policies, and
- Pesticide concentrations shall not exceed the lowest levels technically and economically achievable

The Basin Plan's narrative water quality objective for toxicity states that "…all waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life. This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effect of multiple substances. Compliance with this objective will be determined by analyses of indicator organisms, species diversity, population density, growth anomalies, and biotoxicity tests of appropriate duration or other methods as specified by the Regional Water Board."

Specific numeric water quality objectives for diazinon and chlorpyrifos for the Sacramento County urban waterways have not been established in the Regional Board's Basin Plan.

2.3 Numeric Targets for Diazinon and Chlorpyrifos in Sacramento County Urban Waterways

Federal regulations state "TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate *measure*."[Emphasis added] (40 CFR § 130.2(i)). To identify the appropriate measure, the concentration levels of diazinon and chlorpyrifos that are consistent with the narrative pesticide and toxicity objectives must be identified.

The Regional Board's Basin Plan also includes provisions for interpretation of narrative water quality objectives. The Policy for Application of Water Quality Objectives states that the Regional Board will consider "relevant numerical criteria and guidelines developed and/or published by other agencies and organizations. When considering such criteria, the Board will evaluate whether the specific available numeric criteria are relevant and appropriate and should be applied in determining compliance with the Basin Plan narrative objective."

The Regional Board has reviewed potentially applicable diazinon and chlorpyrifos criteria (Azimi-Gaylon *et al.* 2001). Both the USEPA (USEPA, 1986; USEPA, 2000b) and California Department of Fish and Game (CDFG, Siepmann and Finlayson, 2000) have developed aquatic life water quality criteria using approved USEPA methods (USEPA, 1985). The USEPA finalized national guidelines for chlorpyrifos (USEPA, 1986), but its guidelines for diazinon are in draft (USEPA, 1998).

Methods other than the USEPA methods were evaluated in Azimi-Gaylon and others (2001). Those methods have not been approved for use by the USEPA in the derivation of aquatic life criteria and it is not clear the use of such methods would be protective of aquatic life.

The CDFG criteria were chosen in favor of the USEPA guidelines for chlorpyrifos and diazinon since the CDFG criteria analysis included results from more recent studies. The CDFG criteria for diazinon were also favored over the USEPA criteria, since the CDFG criteria included the results of more recent studies and the CDFG had finalized their criteria. The CDFG water quality criteria are listed in Table 2-2.

Table 2-2. CDFG Criteria for Diazinon and Chlorpyrifos for Determining Toxicity in Sacramento County Urban Waterways

Chemical	Criterion Value	Criterion Type	Criterion Description
Diazinon	0.080 µg/L[1]	Acute	Aquatic life protection; 1-hour average; not to be exceeded more than once every 3 years, on the average
	0.050 µg/L	Chronic	Aquatic life protection; 4-day average; not to be exceeded more than once every 3 years, on the average
Chlorpyrifos	0.020 µg/L	Acute	Aquatic life protection; 1-hour average; not to be exceeded more than once every 3 years, on the average
	0.014 µg/L	Chronic	Aquatic life protection; 4-day average; not to be exceeded more than once every 3 years, on the average

[1] µg/L = micrograms per liter

In addition to the independent effects of diazinon and chlorpyrifos, the additive impacts were also considered since the two chemicals in combination "exhibit additive toxicity when present in solutions together" (Bailey *et al.* 2000). Both the Regional Board's "Policy for Application of Water Quality Objectives" and policy on "Pesticide Discharges from Nonpoint Sources" include formulas for addressing additive toxicity. Additive toxicity can be evaluated by the following formula from the Basin Plan (CVRWQCB, 1998):

$$\frac{C_1}{O_1} + \frac{C_2}{O_2} + \ldots + \frac{C_i}{O_i} = S \qquad \text{[Equation 1]}$$

Where:

C = The concentration of each pesticide (1, 2,…i) measured in a waterbody.

O = The water quality objective or criterion for the specific beneficial use for each pesticide present (1, 2,…i), based on the best available information. Note that the numbers must be acceptable to the Regional Board and performance goals are not to be used in this equation.

S = The sum. A sum exceeding one (1.0) indicates that the beneficial use may be impacted.

The recommended numeric target is 1.0 for the additive effect of diazinon and chlorpyrifos. From Equation 1, the numeric target is exceeded when the sum is greater than 1.0 (i.e. a toxic impact is occurring). The CDFG criteria in Table 2-2 would be the criteria used in Equation 1.

2.4 Sources and Effects of Diazinon and Chlorpyrifos in Surface Water and Rain Water

Diazinon and chlorpyrifos are manufactured insecticides. Hence, the sources for these insecticides detected in the environment (e.g., in Sacramento County urban creeks) are human activities related to pesticide applications. Diazinon and chlorpyrifos are applied in urban and agricultural settings. In urban settings, diazinon and chlorpyrifos are applied by professional pest control personnel, municipal workers, and homeowners to control pests around building foundations, on residential and commercial landscapes and roadways, and at commercial and industrial locations. In agricultural settings in the Sacramento Valley (including Sacramento County), diazinon is primarily applied during the dormant season (January and February) to stone fruit and almond orchards to control boring insects (PUR, 1993 – 2000). This dormant spray season application, although conducted during dry spells, occurs during the winter, which has the highest seasonal rainfall (NCDC, 1990 – 2000). A portion of the applied pesticides volatilizes or dissolves into the atmospheric moisture and migrates (drifts) in fog and rain. Up to 24 percent of the diazinon applied agriculturally may volatilize (Glotfelty *et al.* 1990a). Contaminated rainfall can enter surface waters, either directly or by deposition to the ground and other surfaces and subsequent runoff.

Diazinon and chlorpyrifos can be acutely and chronically toxic to invertebrate (e.g., *Ceriodaphnia dubia*) and vertebrate aquatic life and wildlife (Larkin and Tjeerdema, 2000). When diazinon is metabolized by aquatic organisms it is converted to more powerful (10,000 times) oxon metabolites, such as diazoxon, that causes the toxicity in affected organisms (Sheipline, 1993). Diazinon toxicity is dependent on how rapidly diazinon is converted to diazoxon, and the degradation rate of diazoxon to non-toxic compounds. Diazinon in soil has a half-life of 2 to 4 weeks (Sheipline, 1993). Diazinon in water has a half-life of 12 hours to 6 months (Sheipline, 1993). The actual half-life of diazinon in urban creeks may vary from the reported ranges, depending on temperature, pH, amount of organic content, and other factors.

Diazinon toxicity inhibits an affected organism's acetyl cholinesterase (AChE) enzymes from metabolizing the neurotransmitter acetylcholine (Ach). This causes Ach to accumulate and stimulate prolonged nerve impulse firing, which leads to eventual exhaustion of the organism's nervous system. Acute diazinon poisoning also results in asphyxiation due to respiratory paralysis, causing mortality of the affected organism (Hill, 1995).

Prolonged exposure of freshwater fish to diazinon at lower than lethal concentrations causes spawning to temporarily cease and fish populations to decrease (Sheipline, 1993). However, previously hatched fish exposed to diazinon are not similarly affected suggesting that diazinon has deleterious affects on aquatic organisms that have short reproductive periods (Sheipline, 1993). Generally, diazinon has a moderate potential to bioconcentrate in aquatic organisms; however, the potential for diazinon to bioconcentrate in fish is low. Prolonged exposure at less than lethal concentrations can affect fish fecundity, hatching success, and growth of offspring following long-term parental exposure (Giddings *et al.* 2000).

Chlorpyrifos is a significantly more toxic cholinesterase inhibitor than diazinon yet, unlike diazinon, chlorpyrifos is relatively insoluble in water. Chlorpyrifos adsorbs strongly to soil organic matter, indicating that chlorpyrifos is less likely than diazinon to become mobile in the aquatic environment. Chlorpyrifos, like diazinon, is generally rapidly metabolized by most organisms and does not bioaccumulate or biomagnify in food chains. However, negative physiological effects for many species of freshwater and marine animals were observed during chronic toxicity studies of chlorpyrifos. Chlorpyrifos has also been implicated in fish kills and has caused delayed maturation in fish. Acute toxicity data indicate that, in general, gastropods are the most tolerant of chlorpyrifos while aquatic arthropods (such as C. *dubia* - a water flea and *Mysidopsis bahia*-an opossum shrimp) are the most sensitive (Sheipline, 1993). Reproduction in two sensitive invertebrate species, *Daphnia magna* and *Mysidopsis bahia*, a saltwater mysid, was inhibited due to chlorpyrifos water column concentrations at chronic toxicity levels. Chlorpyrifos is often detected in the water column concurrently with diazinon. Siepmann and Finlayson (2000) analyzed two studies involving the joint toxicity of diazinon and chlorpyrifos to *C. dubia* and determined that chlorpyrifos and diazinon toxicities appear to be additive. Similarly, Bailey *et al.* (1997) found that "…data suggest that diazinon and chlorpyrifos exert additive toxicity to *C. dubia* when both are present in solution."

2.5 Diazinon and Chlorpyrifos Monitoring Data

Since the early 1990s, studies of Sacramento County urban waterways by several agencies, including the Central Valley Regional Board, have shown concentrations of diazinon and, to a lesser extent chlorpyrifos, present at levels that can cause toxicity to some aquatic invertebrate species. Elevated concentrations of diazinon and chlorpyrifos have been detected in rainfall, urban runoff, urban waterways, and sumps that discharge to urban waterways during both rainy and dry seasons.

2.5.1 Arcade Creek - Chlorpyrifos

One hundred eighty three ambient water samples were collected from Arcade Creek between 1994 and 2003. Some of the samples reported as having chlorpyrifos levels below the laboratory reporting limits (0.025 to 0.050 µg/L) may have contained chlorpyrifos at levels above the acute and chronic aquatic life protection criteria (0.020 and 0.014 ug/L, respectively). The data are summarized in Table 2-3.

Five toxicity tests performed using ambient water samples collected from Arcade Creek in November and December 1994 caused significant *Ceriodaphnia* mortality (up to 100% mortality within 96 hours) (UCD ATL, 2000). Additional toxicity tests conducted on stormwater collected from Arcade Creek between 1995 and 2000 indicated that almost every water sample caused significant *Ceriodaphnia dubia* mortality (up to 100% mortality within 48 hours) (Cortright *et al.* 1995; City of Sacramento, 2000; Larsen, 1998).

Table 2-3. Summary of Chlorpyrifos Concentrations in Arcade Creek

Data Source[1]	**Sample Dates (Month/ Year)**	**Number of Samples**	**Range of Chlorpyrifos Concentrations**	**Criteria**[2]		**Number (Percent) of Samples Equal to or Above Criteria**
Cortright *et al.* 1995	5/1995	1	0.081 µg/L	Chronic	0.014 µg/L	1 (100%)
				Acute	0.020 µg/L	1 (100%)
UCD ATL, 2000	10/1994 – 10/1996	18	0.004 – 0.096 µg/L	Chronic	0.014 µg/L	17 (94%)
				Acute	0.020 µg/L	16 (89%)
CDPR SWDB, 2000 Study Code 41 (USGS NAWQA)	11/1996 – 4/1998	30	<0.004 – 0.045 µg/L	Chronic	0.014 µg/L	10 (33%)
				Acute	0.020 µg/L	7 (23%)
Larsen, 1998	8/1996 – 5/1998	13	<0.050 - 0.137 µg/L	Chronic	0.014 µg/L	6 (46%)
				Acute	0.020 µg/L	6 (46%)
City of Sacramento, 2000	11/1999 – 4/2000	16	<0.030 – 0.076 µg/L	Chronic	0.014 µg/L	15 (94%)
				Acute	0.020 µg/L	15 (94%)
Russick, 2001	5/1999 – 5/2000	73	<0.024 – 0.103 µg/L	Chronic	0.014 µg/L	50 (68%)
				Acute	0.020 µg/L	50 (68%)
Larry Walker and Associates, 2002	6/1999 – 6/2001	22	<0.05 µg/L to 1 @ 0.04 µg/L	Chronic	0.014 µg/L	1 (4%)
				Acute	0.020 µg/L	1 (4%)
Spector *et al.*, 2004	1/2003 – 4/2003	10	< 0.004 µg/L to 0.029 µg/L	Chronic	0.014 µg/L	0 (0%)
				Acute	0.020 µg/L	0 (0%)
Summary	10/1994 – 6/2001	183	<0.004 – 0.137 µg/L	Chronic	0.014 µg/L	100 (55%)
				Acute	0.020 µg/L	96 (52%)

1 All sample locations are within the greater Sacramento urban area (DWR, 2000).
2 CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)

The addition of Piperonyl Butoxide (PBO), a substance that inhibits organophosphorus pesticide (like diazinon) toxicity, during Toxicity Identification Evaluation (TIE) tests eliminated the observed toxicity to *Ceriodaphnia*, indicating that the originally observed toxicity was due primarily to organophosphorus (OP) pesticides (including chlorpyrifos). The TIE test results showed that the additive effects of diazinon and chlorpyrifos caused the observed toxicity to *Ceriodaphnia*, and the toxicity could be predicted by the concentrations of diazinon and chlorpyrifos (City of Sacramento, 2000).

2.5.2 Arcade Creek - Diazinon

Three hundred thirty nine ambient water samples have been collected from Arcade Creek and analyzed for diazinon from 1994 to 2003. The data are summarized in Table 2-4.

Table 2-4. Summary of Diazinon Concentrations in Arcade Creek

Data Source[1]	**Sample Dates (Month/ Year)**	**Number of Samples**	**Range of Diazinon Concentrations**	**Criteria[2]**		**Number (Percent) of Samples Equal to or Above Criteria**
Connor, 1994	1/1994	1	0.400 µg/L	Chronic	0.050 µg/L	1 (100%)
				Acute	0.080 µg/L	1 (100%)
Cortright *et al.* 1995	5/1995	1	0.412 µg/L	Chronic	0.050 µg/L	1 (100%)
				Acute	0.080 µg/L	1 (100%)
UCD ATL, 2000	10/1994 – 12/1995	46	0.098 – 0.806 µg/L	Chronic	0.050 µg/L	46 (100%)
				Acute	0.080 µg/L	46 (100%)
Larsen, 1998	8/1996 – 5/1998	13	0.162 – 1.332 µg/L	Chronic	0.050 µg/L	13 (100%)
				Acute	0.080 µg/L	13 (100%)
CDPR SWDB, 2000 Study Code 41 (USGS NAWQA)	11/1996 – 4/1998	30	0.081 – 1.38 µg/L	Chronic	0.050 µg/L	30 (100%)
				Acute	0.080 µg/L	30 (100%)
City of Sacramento, 2000	11/1999 – 4/2000	16	0.129 – 0.748 µg/L	Chronic	0.050 µg/L	16 (100%)
				Acute	0.080 µg/L	16 (100%)
Russick, 2001	5/1999 – 5/2000	73	<0.027 – 0.675 µg/L	Chronic	0.050 µg/L	70 (96%)
				Acute	0.080 µg/L	69 (94%)
Denton, 2001	8/2000 – 7/2001	124	0.100 – 1.40 µg/L	Chronic	0.050 µg/L	124 (100%)
				Acute	0.080 µg/L	124 (100%)
Larry Walker and Associates, 2002	6/1999 – 6/2001	25	<0.05 – 0.830 µg/L	Chronic	0.050 µg/L	19 (76%)
				Acute	0.080 µg/L	18 (72%)
Spector *et al.*, 2004	1/2003 – 4/2003	10	0.062 to 0.220 µg/L	Chronic	0.050 µg/L	10 (100%)
				Acute	0.080 µg/L	9 (90%)
Summary	1/1994 – 7/2001	339	<0.027 to 1.40 µg/L	Chronic	0.050 µg/L	330 (97%)
				Acute	0.080 µg/L	327 (96%)

[1] All sample locations are within the greater Sacramento urban area (DWR, 2000).
[2] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)

The sample collected in January 1994 produced 100% mortality to *Ceriodaphnia* within 24 hours. Five toxicity tests performed using ambient water samples collected from Arcade Creek in November and December 1994 caused significant *Ceriodaphnia* mortality (up to 100% mortality within 96 hours) (UCD ATL, 2000). Additional toxicity tests conducted for various studies on storm-water collected from Arcade Creek between 1995 and 2000 indicated that almost every water sample caused significant *Ceriodaphnia dubia* mortality (up to 100% mortality within 48 hours) (Cortright *et al.* 1995; City of Sacramento, 2000; Larsen, 1998).

The addition of PBO during TIE tests eliminated the observed toxicity to *Ceriodaphnia.* This elimination of toxicity indicates that the originally observed toxicity was due primarily to OP pesticides (including diazinon). The TIE test results showed that the additive effects of diazinon and chlorpyrifos caused the observed toxicity to *Ceriodaphnia*, and the toxicity could be predicted by the concentrations of diazinon and chlorpyrifos. Additionally, "Diazinon was the principal toxicant in the 16 samples… accounting for 57-108% of the total predicted TUs [toxicity units] in the samples" (City of Sacramento, 2000).

2.5.3 Chicken Ranch Slough - Chlorpyrifos

Five ambient water samples were collected by Central Valley Regional Board staff from Chicken Ranch Slough on five dates between November 1994 and April 1995 and analyzed for chlorpyrifos. Chlorpyrifos levels in the five individual samples ranged from 0.028 to 0.191 ug/L (UCD ATL, 2000). Water samples were not collected on four or more consecutive days, so exceedance of the chronic criterion is inferred rather than directly calculated. Since 100% of the samples exceed the chronic criterion, it is possible that the chronic CDFG chlorpyrifos criterion was exceeded, on average and over at least four consecutive days, during the sample period (November 1994 to April 1995). The data are summarized in Table 2-5.

Table 2-5. Summary of Chlorpyrifos Concentrations in Chicken Ranch Slough

Data Source[1]	**Sample Dates (Month/ Year)**	**Number of Samples**	**Range of Chlorpyrifos Concentrations**	**Criteria**[2]		**Number (Percent) of Samples Equal to or Above Criteria**
UCD ATL, 2000	11/1994 – 4/1995	5	0.028 – 0.191 µg/L	Chronic	0.014 µg/L	5 (100%)
				Acute	0.020 µg/L	5 (100%)

1 All sample locations are within the greater Sacramento urban area (DWR, 2000).

2 CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)

Four toxicity tests performed using ambient water samples collected from Chicken Ranch Slough in November 1994 and March 1995 caused significant *Ceriodaphnia* mortality (up to 100% mortality within 2 days) (UCD ATL, 2000).

2.5.4 Chicken Ranch Slough- Diazinon

Sixteen ambient water samples were collected from Chicken Ranch Slough and analyzed for diazinon between January 1994 and April 1995. The data are summarized in Table 2-6.

Water samples were not collected on four or more consecutive days, so exceedance of the chronic criterion is inferred rather than directly calculated. Since 100% of the samples exceed the chronic criterion, it is likely that the chronic CDFG diazinon criterion was repeatedly exceeded, over at least four consecutive days, throughout the sample period.

Table 2-6. Summary of Diazinon Concentrations in Chicken Ranch Slough

Data Source[1]	**Sample Dates (Month/ Year)**	**Number of Samples**	**Range of Diazinon Concentrations**	**Criteria[2]**		**Number (Percent) of Samples Equal to or Above Criteria**
Connor, 1994	1/1994	1	0.625 µg/L	Chronic	0.050 µg/L	1 (100%)
				Acute	0.080 µg/L	1 (100%)
UCD ATL, 2000	11/1994 – 4/1995	15	0.057 – 0.549 µg/L	Chronic	0.050 µg/L	15 (100%)
				Acute	0.080 µg/L	14 (93%)
Summary	1/1994 – 4/1995	16	0.057 – 0.625 µg/L	Chronic	0.050 µg/L	16 (100%)
				Acute	0.080 µg/L	15 (94%)

[1] All sample locations are within the greater Sacramento urban area (DWR, 2000).

[2] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)

The sample collected in January 1994 that contained 0.625 ug/L diazinon produced 100% mortality to *Ceriodaphnia* within 24 hours. Four additional toxicity tests performed using ambient water samples collected from Chicken Ranch Slough in November 1994 and March 1995 caused significant *Ceriodaphnia* mortality (up to 100% mortality within 2 days) (UCD ATL, 2000).

2.5.5 Elder Creek - Chlorpyrifos

Thirty nine ambient water samples collected from Elder Creek between October 1994 and December 1995, in February 2001, and between January and April 2003 were analyzed for chlorpyrifos. The data are summarized in Table 2-7. Water samples were not collected on four or more consecutive days, so exceedance of the chronic criterion is inferred rather than directly calculated. In addition, the detection limit used for some of the samples was 0.050 ug/L, which is greater than both the chronic and acute criteria. Since 56% of the samples exceed the chronic criterion, it is likely that the chronic CDFG chlorpyrifos criterion was exceeded, on average and over at least four consecutive days, during the sample period (October 1994 to December 1995).

Five of six toxicity tests performed using ambient water samples collected from Elder Creek between October and December 1994 caused significant *Ceriodaphnia* mortality (up to 100% mortality within 96 hours) (UCD ATL, 2000). Toxicity tests conducted on *Ceriodaphnia* using a sample collected from Elder Creek on April 29, 1995 caused 100% mortality after 4 days. The addition of PBO to the sample during TIE tests eliminated the toxicity, suggesting that the toxicity was due to organophosphorus pesticides (Cortright *et al.* 1995). This sample contained chlorpyrifos at 0.090 µg/L (Cortright *et al.* 1995).

Table 2-7. Summary of Chlorpyrifos Concentrations in Elder Creek

Data Source	**Sample Dates (Month/ Year)**	**Number of Samples**	**Range of Chlorpyrifos Concentrations**	**Criteria[1]**		**Number (Percent) of Sample Dates Equal to or Above Criteria**
UCD ATL, 2000[2]	10/1994 - 12/1995	9	0.031 – 0.129 µg/L	Chronic	0.014 µg/L	9 (100%)
				Acute	0.020 µg/L	9 (100%)
Spector and Harader (2001)	2/2001	3	ND	Chronic	0.014 µg/L	0 (0%)
				Acute	0.020 µg/L	0 (0%)
Spector and Harader (2001)[2]	2/2001	2	ND	Chronic	0.014 µg/L	0 (0%)
				Acute	0.020 µg/L	0 (0%)
Spector *et al.*, 2004	1/2003 – 4/2003	20	<0.007 – 0.320 µg/L	Chronic	0.014 µg/L	10 (50%)
				Acute	0.020 µg/L	8 (40%)
Summary	10/1994 – 12/1995 & 2/2001	34	ND – 0.320	Chronic	0.014 µg/L	19 (56%)
				Acute	0.020 µg/L	17 (50%)

ND = Not Detected

[1] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)

[2] Sample locations are within the greater Sacramento urban area (DWR, 2000).

2.5.6 Elder Creek - Diazinon

Fifty one ambient water samples were collected from Elder Creek in 1994, 1995, 2001 and 2003 and analyzed for diazinon. The data are summarized in Table 2-8. Water samples were not collected on four or more consecutive days, so exceedance of the chronic criterion is inferred rather than directly calculated. Since 43% of the samples exceeded the chronic criterion, it is likely the four-day average concentration also frequently exceeded the chronic criterion.

The sample collected in January 1994 produced 100% mortality to *Ceriodaphnia* within 24 hours. Five toxicity tests performed using ambient water samples collected from Elder Creek in November and December 1994 caused significant *Ceriodaphnia* mortality (up to 100% mortality within 96 hours) (UCD ATL, 2000). Toxicity tests conducted on *Ceriodaphnia* using a water sample collected from Elder Creek on April 29, 1995 caused 100% mortality after 4 days. The addition of PBO to the sample during TIE tests eliminated the toxicity, suggesting that the toxicity was due to organophosphorus pesticides (Cortright *et al.* 1995).

2.5.7 Elk Grove Creek - Diazinon

Twelve ambient water samples collected between January 1995 and March 1995 and four ambient water samples collected in February 2001 from Elk Grove Creek were analyzed for diazinon. The data are summarized in Table 2-9. Water samples were not collected on four or more consecutive days, so exceedance of the chronic criterion is inferred rather than directly calculated. Since 75% of the samples exceeded the chronic criterion, it is likely the four-day average concentration also frequently exceeded the chronic criterion.

2.5.8 Morrison Creek - Diazinon

Forty ambient water samples collected from Morrison Creek in January 1994, between November 1994 and March 1995, in February 2001, and between January and April 2003 were analyzed for diazinon. The data are summarized in Table 2-10. Water samples were not collected on four or more consecutive days, so exceedance of the chronic criterion is inferred rather than directly calculated. Since 52% of the samples exceed the chronic criterion, it is likely the four-day average concentration also frequently exceeded the chronic criterion.

The water sample collected in January 1994 produced 100% mortality to *Ceriodaphnia* within 24 hours. Toxicity tests conducted on four water samples collected from Morrison Creek between November 1994 and January 1995 showed significant survival impairment (up to 100% mortality within 72 hours) to *Ceriodaphnia dubia* in three of the samples (UCD ATL, 2000).

Table 2-8. Summary of Diazinon Concentrations in Elder Creek

Data Source	**Sample Dates (Month/ Year)**	**Number of Samples**	**Range of Diazinon Concentrations**	**Criteria[1]**		**Number (Percent) of Samples Equal to or Above Criteria**
Connor, 1994[2]	1/1994	2	>0.5 and 1.10 µg/L	Chronic	0.050 µg/L	2 (100%)
				Acute	0.080 µg/L	2 (100%)
UCD ATL, 2000[2]	10/1994 – 12/1995	19	<0.030 – 0.840 µg/L	Chronic	0.050 µg/L	17 (89%)
				Acute	0.080 µg/L	15 (79%)
Spector and Harader, 2001	2/2001	3	ND	Chronic	0.050 µg/L	0 (0%)
				Acute	0.080 µg/L	0 (0%)
Spector and Harader, 2001[2]	2/2001	2	<0.050 – 0.170 µg/L	Chronic	0.050 µg/L	1 (50%)
				Acute	0.080 µg/L	1 (50%)
Spector *et al.*, 2004	1/2003 – 4/2003	20	<0.007 – 0.030 µg/L	Chronic	0.050 µg/L	0 (0%)
				Acute	0.080 µg/L	0 (0%)
Summary	1/1994-12/1995 & 2001	46	<0.030 – 1.10 µg/L	Acute	0.080 µg/L	20 (43%)
				Chronic	0.050 µg/L	17 (37%)

[1] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)
[2] Sample locations are within the greater Sacramento urban area (DWR, 2000).

Table 2-9. Summary of Diazinon Concentrations in Elk Grove Creek

Data Source[1]	Sample Dates (Month/ Year)	Number of Samples	Range of Diazinon Concentrations	Criteria[2]		Number (Percent) of Samples Equal to or Above Criteria
UCD ATL, 2000	1/1995-3/1995	12	0.034 – 0.803 µg/L	Chronic	0.050 µg/L	10 (83%)
				Acute	0.080 µg/L	10 (83%)
Spector and Harader, 2001	2/2001	4	<0.050 – 0.38 µg/L	Chronic	0.050 µg/L	2 (50%)
				Acute	0.080 µg/L	2 (50%)
Summary	1/1995 – 3/1995 & 2/2001	16	<0.050 – 0.803 µg/L	Chronic	0.050 µg/L	12 (75%)
				Acute	0.080 µg/L	12 (75%)

[1] All sample locations are within the greater Sacramento urban area (DWR, 2000).

[2] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)

Table 2-10. Summary of Diazinon Concentrations in Morrison Creek

Data Source	Sample Dates (Month/ Year)	Number of Samples	Range of Diazinon Concentrations	Criteria[1]		Number (Percent) of Samples Equal to or Above Criteria
Connor, 1994[2]	1/1994	2	0.340 and >0.5 µg/L	Chronic	0.050 µg/L	2 (100%)
				Acute	0.080 µg/L	2 (100%)
UCD ATL, 2000[2]	11/1994-3/1995	10	<0.045 - 0.334 µg/L	Chronic	0.050 µg/L	9 (90%)
				Acute	0.080 µg/L	9 (90%)
Spector and Harader, 2001	2/2001	7	<0.050 – 0.10 µg/L	Chronic	0.050 µg/L	2 (28%)
				Acute	0.080 µg/L	1 (14%)
Spector and Harader, 2001[2]	2/2001	1	0.09 µg/L	Chronic	0.050 µg/L	1 (100%)
				Acute	0.080 µg/L	1 (100%)
Spector *et al.*, 2004	1/2003 – 4/2003	10	<0.004 – 0.014 µg/L	Chronic	0.050 µg/L	0 (0%)
				Acute	0.080 µg/L	0 (0%)
Spector *et al.*, 2004[2]	1/2003 – 4/2003	10	<0.004 – 0.16 µg/L	Chronic	0.050 µg/L	7 (70%)
				Acute	0.080 µg/L	5 (50%)
Summary	1/1994 – 3/1995 & 2/2001	40	<0.050 – >0.50 µg/L	Chronic	0.050 µg/L	21 (52%)
				Acute	0.080 µg/L	18 (45%)

[1] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)
[2] Sample locations are within the greater Sacramento urban area (DWR, 2000).

2.5.9 Strong Ranch Slough - Chlorpyrifos

Thirty-nine ambient water samples were collected from Strong Ranch Slough between October 1994 and May 2000 and were analyzed for chlorpyrifos. The data are summarized in Table 2-11. Water samples were not collected on four or more consecutive days, so exceedance of the chronic criterion is inferred rather than directly calculated. Since 97% of the samples exceed the chronic criterion, it is likely the four-day average concentration also frequently exceeded the chronic criterion.

Toxicity tests conducted on four ambient water samples collected from Strong Ranch Slough between October and November 1994 caused survival impairment (100% mortality within 2 days) to *Ceriodaphnia* in all four samples (UCD ATL, 2000). Toxicity tests conducted on a sample collected from Strong Ranch Slough in April 1995 caused survival impairment (100% mortality within 1 day) to *Ceriodaphnia*. The addition of PBO to the sample during TIE tests reduced the toxicity, suggesting that the toxicity was due, at least in part, to organophosphorus pesticides (Cortright *et al.* 1995).

Table 2-11. Summary of Chlorpyrifos Concentrations in Strong Ranch Slough

Data Source[1]	**Sample Dates (Month/ Year)**	**Number of Samples**	**Range of Chlorpyrifos Concentrations**	**Criteria[2]**		**Number (Percent) of Samples Equal to or Above Criteria**
UCD ATL, 2000	10/1994-4/1995	8	0.070 – 0.117 µg/L	Chronic	0.014 µg/L	8 (100%)
				Acute	0.020 µg/L	8 (100%)
Russick, 2001	3/1995-5/2000	31	<0.030 – 0.53 µg/L	Chronic	0.014 µg/L	30 (96%)
				Acute	0.020 µg/L	28 (90%)
Summary	10/1994 – 4-1995 & 5/1999 – 5/2000	39	<0.030 – 0.53 µg/L	Chronic	0.014 µg/L	38 (97%)
				Acute	0.020 . µg/L	36 (92%)

[1] All sample locations are within the greater Sacramento urban area (DWR, 2000).

[2] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)

2.5.10 Strong Ranch Slough - Diazinon

Forty-nine ambient water samples were collected from Strong Ranch Slough and analyzed for diazinon. The data are summarized in Table 2-12. Water samples were not collected on four or more consecutive days, so exceedance of the chronic criterion is inferred rather than directly calculated. Since 96% of the samples exceed the chronic criterion, it is likely the four-day average concentration also frequently exceeded the chronic criterion.

The water sample collected in January 1994 produced 100% mortality to *Ceriodaphnia* within 24 hours. Toxicity tests conducted on four ambient water samples collected from Strong Ranch Slough between October and November 1994 caused survival impairment (100% mortality within 2 days) to *Ceriodaphnia* in all four samples (UCD ATL, 2000). Toxicity tests conducted on a runoff-based sample collected from Strong Ranch Slough in April 1995 caused survival impairment (100% mortality within 1 day) to *Ceriodaphnia*. The addition of PBO to the sample during TIE tests reduced the toxicity, suggesting that the toxicity was due, at least in part, to organophosphorus pesticides (Cortright *et al.* 1995).

Regional Board staff evaluations have concluded that the narrative WQOs for pesticides and toxicity are not being attained in the six waterways described in this TMDL because of ongoing occurrences of diazinon and chlorpyrifos in the waterways at concentrations toxic to aquatic life.

Table 2-12. Summary of Diazinon Concentrations in Strong Ranch Slough

Data Source[1]	**Sample Dates (Month/ Year)**	**Number of Samples**	**Range of Diazinon Concentrations**	**Criteria[2]**		**Number (Percent) of Samples Equal to or Above Criteria**
UCD ATL, 2000	10/1994-12/1995	18	0.049 to 1.547 µg/L	Chronic	0.050 µg/L	17 (94%)
				Acute	0.080 µg/L	17 (94%)
Russick (2001)	5/1999 – 5/2000	31	0.040 – 2.18 µg/L	Chronic	0.050 µg/L	30 (98%)
				Acute	0.080 µg/L	29 (94%)
Summary	10/1994-12/1995 & 5/1999 – 5/2000	49	0.040 – 2.18 µg/L	Chronic	0.050 µg/L	47 (96%)
				Acute	0.080 µg/L	46 (94%)

[1] All sample locations are within the greater Sacramento urban area (DWR, 2000).

[2] CDFG water quality criteria for the protection of aquatic life (Siepmann and Finlayson, 2000)

3. SOURCE ANALYSIS

This section describes the historical and projected future uses of diazinon and chlorpyrifos.

3.1 Diazinon and Chlorpyrifos Use

Pesticides containing the active ingredients diazinon and chlorpyrifos are the most heavily used pesticides in Sacramento County (Russick, 2001). These pesticides are primarily used by residential homeowners, pest control operators (PCOs) in the urban environment, and farmers/growers in the agricultural environment to control insect infestations in and around structures, on landscaping and in crop fields. The amount of pesticides applied by PCOs and farmers/growers are reported to the California Department of Pesticide Regulation. However, residential homeowner use of diazinon and chlorpyrifos is not required to be reported, so estimating complete historical diazinon and chlorpyrifos use in the urban environment requires indirect methods (in section 3.1.2).

Prior to cancellation of residential uses, approximately 75 percent of diazinon products sold were used in and around homes in the United States with diazinon products accounting for 30 percent of the homeowner-use insecticide market. Home lawn care use accounted for the majority of residential use of diazinon products (USEPA, 2001a). Chlorpyrifos was also a widely used insecticide in the United States, with nearly 50 percent of chlorpyrifos products used in and around the home prior to cancellation of many of these uses (USEPA, 2000c).

Diazinon and chlorpyrifos are used in the agricultural environment on a variety of orchards and crops. From 1966 to 1988, organophosphorus pesticides, including diazinon and chlorpyrifos, accounted for 65 percent of insecticides used in agriculture in the United States. Heavy use of other organophosphorus insecticides, such as chlorpyrifos, methyl parathion, parathion, and Malathion, has also occurred for decades (Majewski and Capel, 1995).

The most common reported use of diazinon and chlorpyrifos in Sacramento County is for urban structural pest control. The second most common use is for agriculture and the third most common use is on urban landscaping (CDPR PUR, 1993-2000).

According to Moran (2001), almost half of all urban chlorpyrifos applications are to control termites in structures, where applications occur both underground and above ground. Sewer discharges containing diazinon and chlorpyrifos can occur due to indoor releases at commercial facilities and residences. Illegal dumping of these insecticides directly into surface waters or storm drains may occur, but previous studies do not show highly variable concentrations that would indicate such event-based releases (Moran, 2001).

3.1.1 Historical USEPA Registered Uses

As of May 2001, there were 171 reported total urban sites of use (defined as types of use, e.g., structural pest control or almonds) for diazinon, and 148 reported urban sites of use for chlorpyrifos in California. The majority of diazinon and chlorpyrifos products are registered for multiple sites of use. The USEPA and the CDPR determine the allowable sites of use for each pesticide product during the pesticide registration process. Pesticides cannot legally be applied to non-registered sites of use. Of the total urban sites of use, 33 diazinon and 68 chlorpyrifos urban sites of use are likely to cause water quality problems (Moran, 2001). Since May 2001, USEPA registrations for diazinon and chlorpyrifos products and their associated sites of use have changed considerably, with many sites of use being eliminated. Additional sites of use are under USEPA consideration for cancellation or restricted use.

Table 3-1 lists the total amounts of diazinon and chlorpyrifos reported as used in Sacramento County from January 1993 through December 2002 by the six main categories of use. Figures 3-1 and 3-2 show the diazinon and chlorpyrifos use trends, respectively, by these same six categories for the period 1993 – 2002. Figures 3-3 and 3-4 show the average annual agricultural diazinon and chlorpyrifos applications, respectively, by geodetic section in relation to urban land area (DWR, 2000) and the impaired creeks that are the subject of this TMDL report. These figures show that the majority of the reported diazinon and chlorpyrifos agricultural applications occurs south of the impaired urban creeks and the greater Sacramento urban area.

Table 3-1. Average Annual Reported Diazinon and Chlorpyrifos Use in Sacramento County, 1993-2002

Sacramento County Sites of Use	Average Annual Pounds of Diazinon	Average Annual Pounds of Chlorpyrifos
STRUCTURAL PEST CONTROL	8,648	30,150
AGRICULTURE PRODUCTS[1,2]	4,947	5,167
LANDSCAPE MAINTENANCE	660	1,007
REGULATORY PEST CONTROL	13	17
RIGHTS OF WAY	67	6
PUBLIC HEALTH PEST CONTROL	Not Applicable	9

Diazinon and chlorpyrifos use data was obtained from the Department of Pesticide Regulation Pesticide Use Report Database, 1993-2002.

1. Diazinon agricultural uses: pear, tomato, apple, tomatoes for processing/canning, peach, sugar beet (general), cherry, walnut (English & Persian), grapes and wine grapes, almond, peppers (fruiting vegetable; Bell, Chili, etc.), corn for human consumption, squash (all or unspecified), green onions, plums (wild and for human consumption), nectarine, kale, nursery plants (field & greenhouse grown plants in containers & greenhouse grown cut flowers or greens), melons, cucumbers (pickling, Chinese), apricot, mustard (general), strawberry (all or unspecified), collards, watermelons, radish, cantaloupe, Christmas tree plantations, Swiss chard, beets (general), and greenhouse grown transplant/propagative material.
2. Chlorpyrifos agricultural uses: alfalfa (forage-fodder, alfalfa hay), apple, asparagus (spears, ferns, etc.), corn: human consumption and corn (forage-fodder), nursery plants (field & greenhouse grown plants in containers and greenhouse grown transplant/propagative material), peach, pear, radish, sorghum/milo general, strawberry (all or unspecified), Sudangrass (forage-fodder, Sorghum Sudanese), sugarbeet (general), sunflower (general), and walnut (English walnut, Persian walnut).

Figure 3-1. Total Diazinon Use (lbs) by Application Type for 1993 - 2002

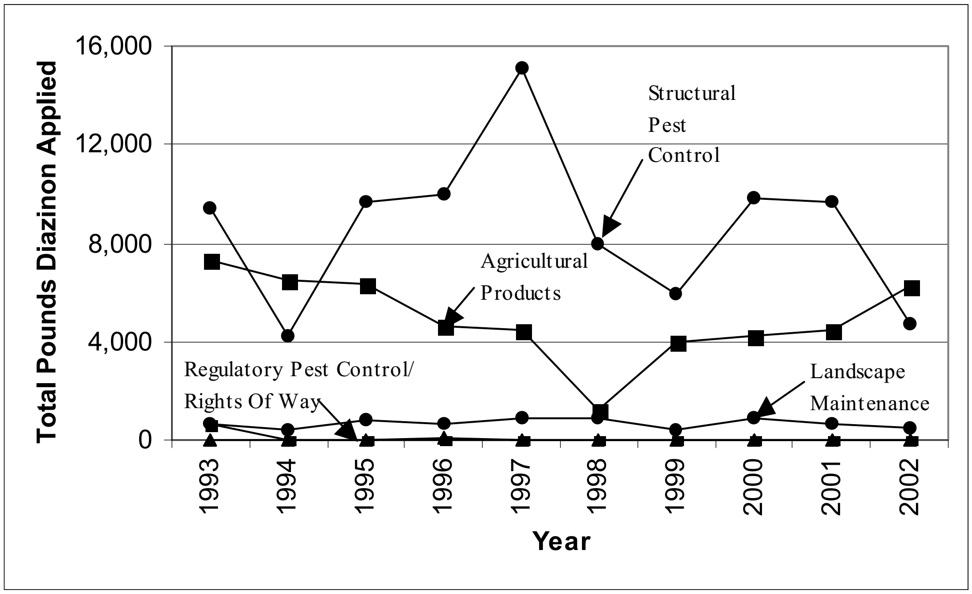
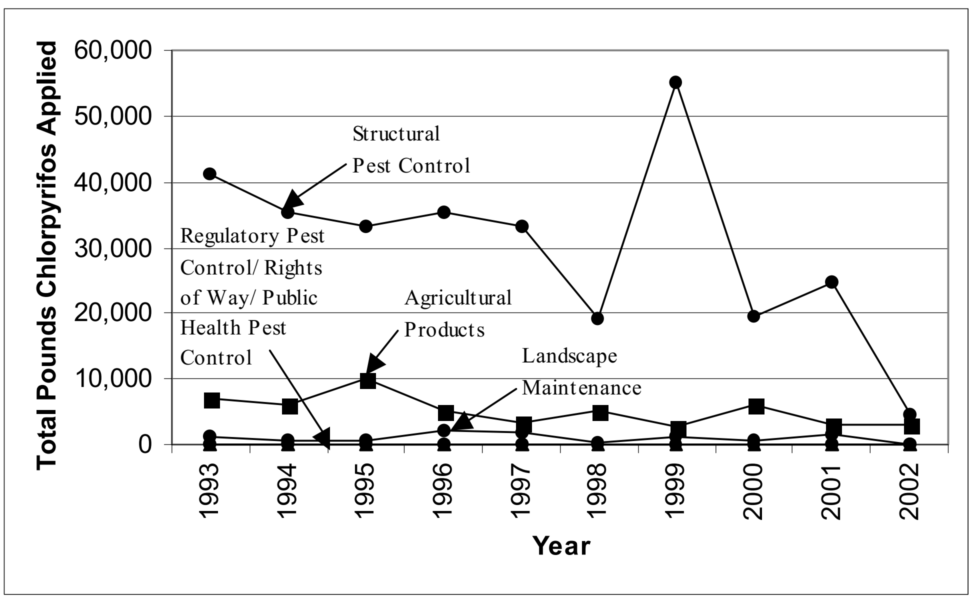


Figure 3-2. Total Chlorpyrifos Use (lbs) by Application Type for 1993 - 2002



3.1.2 Estimated Unreported Pesticide Use

Unreported diazinon and chlorpyrifos uses in Sacramento County were estimated based on diazinon and chlorpyrifos sales and use information determined in the Survey of Residential Pesticide Use and Sales in the San Diego Creek watershed of Orange County, California (Wilen, 2001). The estimated unreported use for Sacramento County was found by multiplying the ratio of the Sacramento to Orange county populations by the estimated unreported use for Orange County found by Wilen. Using this approach, the

Regional Board determined that approximately 46 percent of diazinon active ingredient use and 4 percent of chlorpyrifos active ingredient use in Sacramento County is unreported use. Figures 3-5 and 3-6 depict the comparison between reported and estimated unreported residential diazinon and chlorpyrifos uses in Sacramento County for 2002.

Figure 3-3. Average Annual Agricultural Diazinon Use 2000 – 2002 (lbs)

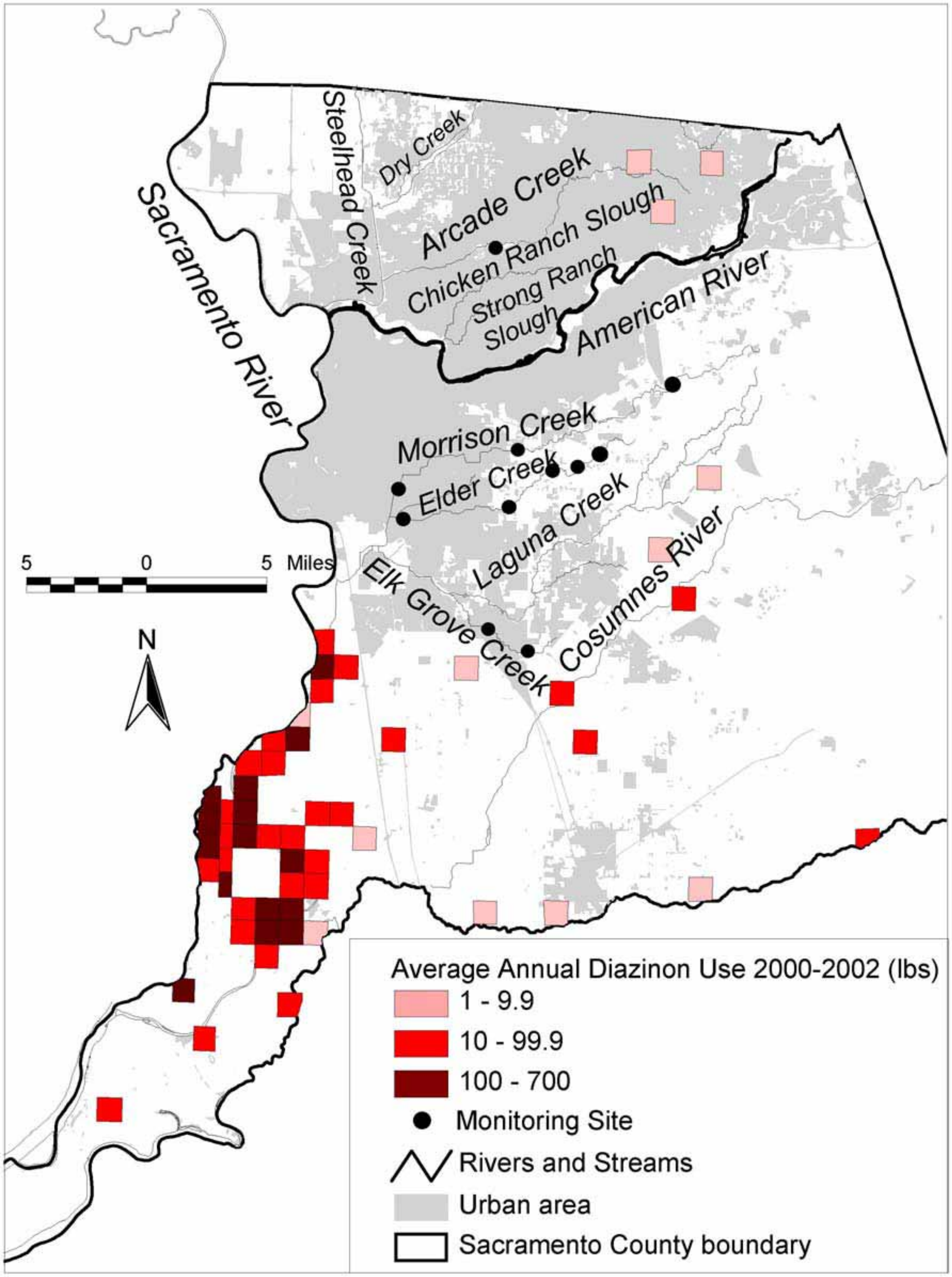


Figure 3-4. Average Annual Agricultural Chlorpyrifos Use 2000 – 2002 (lbs)

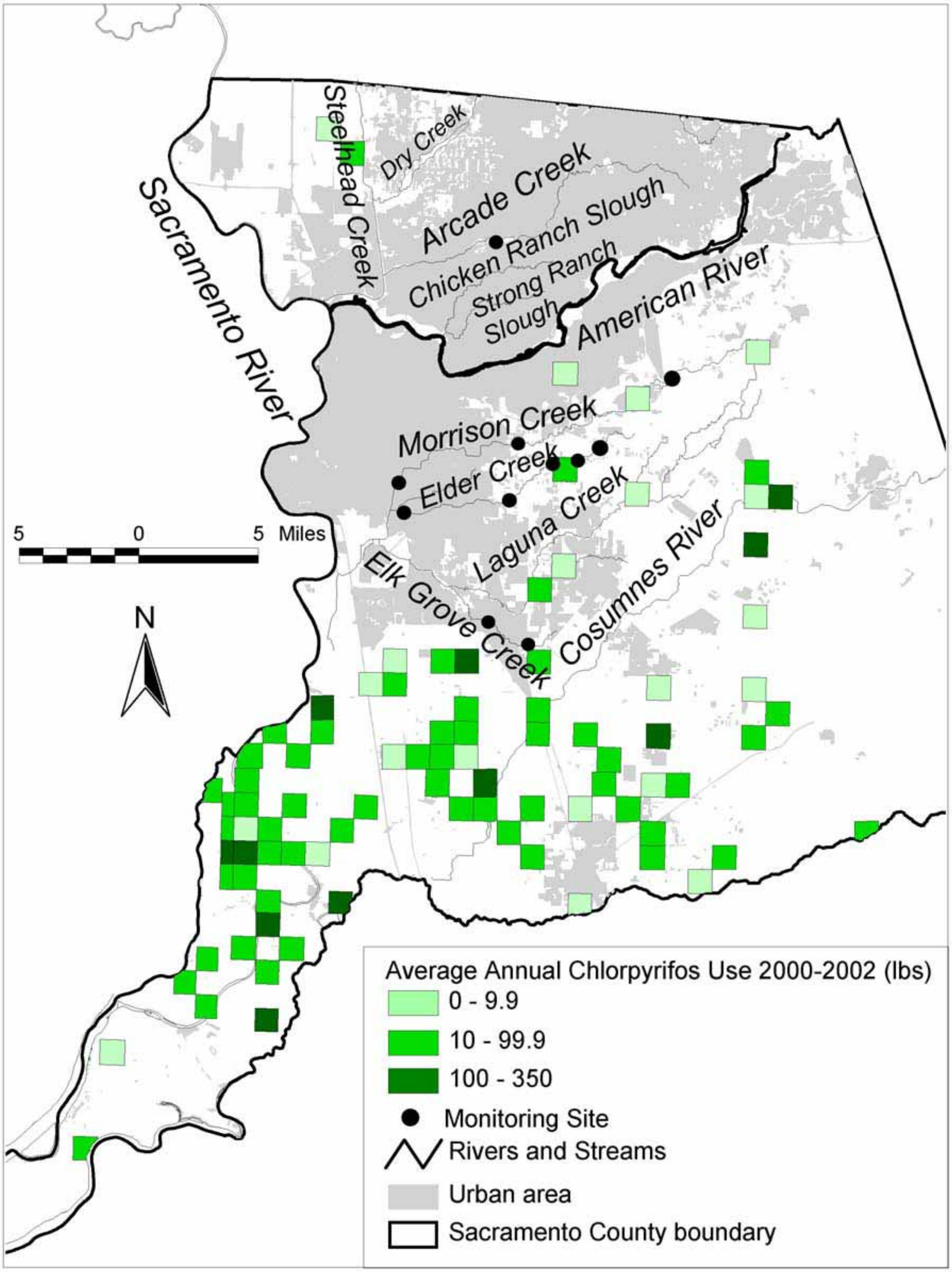
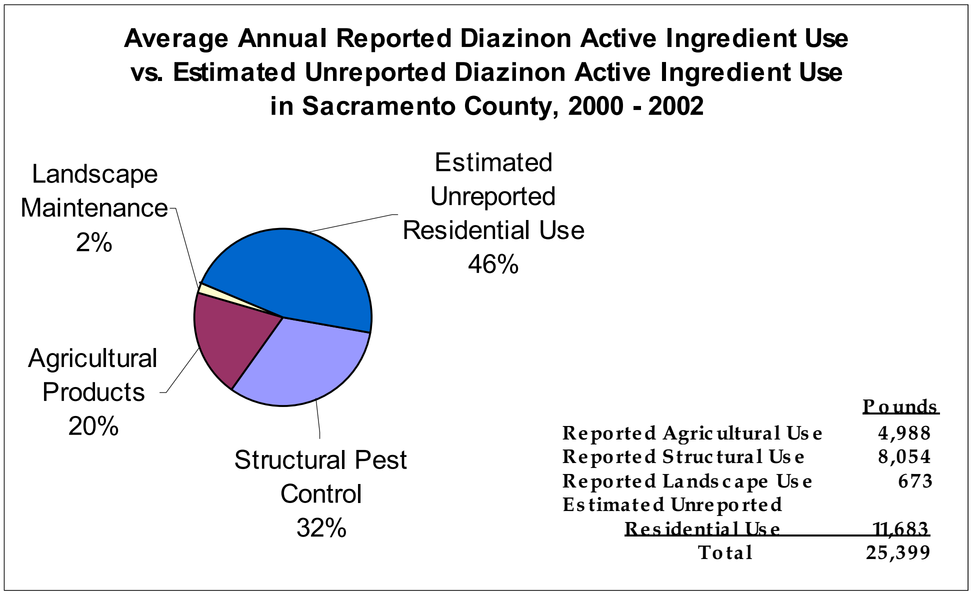
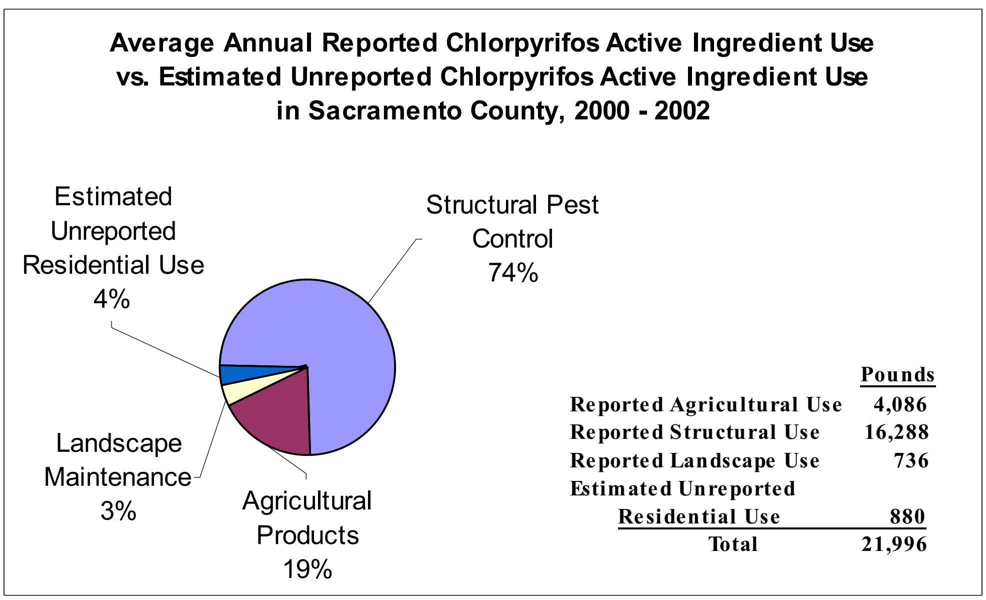


Figure 3-5. Average Annual Reported and Estimated Unreported Residential Diazinon Use in Sacramento County, 2000 – 2002



*Diazinon use for regulatory pest control, right-of-ways and public health pest control in Sacramento County was not reported in 2002.

Figure 3-6. Average Annual Reported and Estimated Unreported Residential Chlorpyrifos Use in Sacramento County, 2000 - 2002



*Chlorpyrifos average annual use for regulatory pest control and right-of-ways in Sacramento County in 2000- 2002 was negligible (approximately 2 pounds for each). Chlorpyrifos use for public health pest control was not reported in 2002.

3.1.3 Projected USEPA Registered Uses

As a result of agreements between the USEPA and diazinon and chlorpyrifos technical registrants (USEPA, 2000c and USEPA, 2001a), nearly 30 agricultural uses of diazinon are no longer allowed on specific crops or sites-of-use, including pastures, rangeland and sheep. Two agricultural uses of chlorpyrifos (on tomatoes and post-bloom use on apples) are not allowed and the maximum application rate has been lowered for one crop (grapes) (see Tables A-1 and A-2 in Appendix A). Approximately 100 percent of diazinon and approximately 95 percent of chlorpyrifos use on specific Sacramento County-grown agricultural crops will continue, pursuant to the 2000 agreement between the USEPA and the technical registrants and to the proposed diazinon and chlorpyrifos Interim Reregistration Eligibility Decisions (IREDs; USEPA, 2002a and USEPA, 2001b, respectively). Discussions are currently underway between the USEPA and the diazinon and chlorpyrifos technical registrants to potentially restrict or eliminate several additional agricultural uses of diazinon (as proposed in the 2002 Diazinon IRED) and chlorpyrifos (as proposed in the 2001 Chlorpyrifos IRED). Tables A-3 and A-4, in Appendix A, list crops grown in Sacramento County that received diazinon or chlorpyrifos applications in 2000 and estimate future diazinon and chlorpyrifos uses in Sacramento County in light of both the agreement between the USEPA and the technical registrants and the diazinon and chlorpyrifos IREDs.

Formal agreements between the USEPA and the primary diazinon technical registrants in 2000 canceled product registrations and banned retail sales of all indoor urban diazinon products by December 31, 2002 and all outdoor non-agricultural (urban) diazinon products by December 31, 2004 (USEPA, 2001a).

The use of chlorpyrifos products in the urban environment is more complex, as several chlorpyrifos uses will still be registered. The agreement between the USEPA and the primary chlorpyrifos technical registrants calls for: canceling registrations and phasing out most indoor and outdoor residential chlorpyrifos uses; limiting application rates on urban outdoor chlorpyrifos use; and limiting chlorpyrifos use for mosquito control and fire ants to certified professional pest control operators who must report their uses (USEPA, 2000c).

The USEPA phase-out (by December 31, 2001) first eliminated the uses of diazinon and chlorpyrifos that provide the greatest risk for exposure to children in the urban environment (home lawn, indoor crack and crevice, whole house ‘post-construction’ treatments, and schools and parks) and allowed the continuation of remaining diazinon and chlorpyrifos uses for specific periods to ensure an orderly transition to appropriate pesticide alternatives. Tables A-1 and A-2 in Appendix A summarize the provisions of the 2000 agreements between the USEPA and the diazinon and chlorpyrifos technical registrants, respectively, and list the phase-out schedules for urban and agricultural registered uses of diazinon and chlorpyrifos. Chlorpyrifos products that remain registered for use in the urban environment (listed in Table A-5 in Appendix A), and some agricultural uses of diazinon and chlorpyrifos that can occur in urban areas (such as nurseries, mushroom houses, and greenhouses), are potentially ongoing sources in Sacramento County urban watersheds (Moran, personal comm., 2002).

Nurseries in Sacramento County reportedly applied annual average amounts of approximately 6 and 56 pounds of diazinon and chlorpyrifos, respectively, between 1993 and 2000 (CDPR PUR, 1993-2000). Diazinon and chlorpyrifos are applied to field-grown plants, outdoor- and greenhouse–grown container plants, and to transplanted and propagative plant materials (Table 3-2), particularly in the Morrison Creek and Elder Creek watersheds. Diazinon is also applied to greenhouse-grown cut flowers and greens.

Table 3-2. Reported Diazinon and Chlorpyrifos Use at Nurseries, 1993-2002 (in Annual Average Pounds and Percent of 10-Year Annual Average Diazinon or Chlorpyrifos Use Within Sacramento County)

Type of Nursery Use	Diazinon	Chlorpyrifos
Greenhouse grown cut flowers or greens	0.47 (0.003%)	0.21 (0.0005%)
Greenhouse grown plants in containers	0.16 (0.0009%)	2.4 (0.005%)
Greenhouse grown transplant/propagative material	0.28 (0.002%)	0.46 (0.001%)
Outdoor container/Field grown plants	8.4 (0.05%)	76.7 (0.17%)

Non-agricultural (urban) registered diazinon uses (Table A-1, Appendix A) have not undergone the rapid phase-out schedule in comparison to the urban chlorpyrifos use phase-out (Table A-2, Appendix A). Formulation of chlorpyrifos products for many cancelled chlorpyrifos sites of use stopped in December 2000 and the sale of these products by formulators ceased in February 2001. However, several uses still remain (Table A-2).

Registered diazinon uses in the urban environment will cease by the end of 2004 (when final registration cancellations go into effect that involve diazinon use for landscape maintenance and any other outdoor residential or outdoor non-agricultural uses). However, individual homeowners that have purchased diazinon products prior to the stop-sale date of December 2004 can continue to use their supply of diazinon and, therefore, continue to be a potential source for diazinon in Sacramento County urban creeks.

Chlorpyrifos use for pre-construction termite control is allowed through 2005 and many remaining registered urban chlorpyrifos uses that are allowed thereafter are discussed below. Formulation and sale of post-construction chlorpyrifos termiticide products ceased as of December 2001. Since chlorpyrifos use in the urban environment in Sacramento County is largely performed by PCOs for structural pest control applications, and estimated residential use of chlorpyrifos is low (4 percent), water quality impairments from urban chlorpyrifos use are potentially less likely in the future.

Outdoor Public Health, Manhole Covers and Road Medians

Outdoor urban chlorpyrifos uses for public health (applications to fire ant mounds, for mosquito control, and to manhole covers) and road medians are still allowed by the USEPA. However, the USEPA prohibits chlorpyrifos use on manholes in storm drain systems, but still allows chlorpyrifos use on manholes in sewer systems (USEPA, 2002b). Historically, use of chlorpyrifos for public health or road medians has been about 0.1% of total use. It is unlikely that reductions in use would be needed for these types of applications to meet water quality objectives. Since these applications are generally conducted by government agencies, such applications can readily be reduced, if necessary.

Outdoor Golf Course-Landscape Maintenance

Most incidents of bird kills from 1974 to 1992 occurred following chlorpyrifos treatments on golf courses and on lawns. Aquatic mortality incidents related to perimeter applications of chlorpyrifos around residences also occurred during this period (USEPA, 2001b). To mitigate this problem, the agreement between the USEPA and the chlorpyrifos registrants requires that the maximum chlorpyrifos application rate for landscape maintenance at golf courses be reduced from four pounds per acre to one pound per acre (a 75 percent use reduction).

Projecting the impact of continued outdoor chlorpyrifos use at Sacramento County golf courses is difficult, as this use is reported to the CDPR under the landscape maintenance use category that includes other uses, and also because historical uses of pesticides at most golf courses in Sacramento County is unknown.

In Sacramento County there are approximately 25 golf courses of which 8 are owned by Sacramento County or the City of Sacramento and 17 are privately owned (Sacramento.com, 2001). Regional Board staff contacted the Sacramento County Golf Division, Golf Manager and found that chlorpyrifos use at three Sacramento County-owned golf courses is minimal: chlorpyrifos is used at one county-owned golf course (Ancil Hoffman Golf Course) when an outbreak of cutworms occurs (diazinon is no longer used), and chlorpyrifos (and diazinon) are not used at the other two county-owned golf courses (Cherry Island and Mather Golf Courses) (Gwaltney and Oliver, pers. comm., 2002). Chlorpyrifos and diazinon use practices at Sacramento city-owned and privately-owned golf courses are not known.

The USEPA-mandated reduction (75%) in chlorpyrifos maximum application rates at golf courses could result in a reduction in chlorpyrifos runoff to Sacramento County urban creeks. Chlorpyrifos use at the City-owned and privately-owned golf courses in Sacramento County may need to be evaluated as an urban source of chlorpyrifos, if chlorpyrifos levels in Sacramento County urban waterways still exceed numeric targets.

Outdoor Industrial Sites

The USEPA has mandated a chlorpyrifos application rate reduction for outdoor industrial plant site use, from four pounds per acre to a maximum of one pound per acre (potentially a 75 percent reduction of chlorpyrifos use). Projecting the impact that continued outdoor chlorpyrifos use at Sacramento County industrial plant sites could have on urban waterways is difficult, as reporting of chlorpyrifos use at industrial sites is not required by the CDPR and, hence, no historical use records are available to serve as a baseline for projecting future uses.

Some industrial area runoff studies in Sacramento County can serve as a baseline to compare future chlorpyrifos use rates and associated concentrations. Samples from Sump 111, which drains a 419-acre industrial area in Sacramento County, contained a median chlorpyrifos concentration of 0.027 μg/L and exceeded the CDFG acute water quality criterion (0.020 μg/L) 51 percent of the time. For the 1991-2000 Sump 111 data record, particularly high chlorpyrifos concentrations occurred from October-December and elevated chlorpyrifos concentrations were measured throughout the year (Bailey *et al.* 2000 and Russick, 2001). If concentrations of chlorpyrifos in urban waterways are reduced as much as the allowed application rates at outdoor industrial sites are reduced, the median concentration in Sump 111 could be 0.007 μg/L (below the CDFG acute water quality criterion).

Outdoor Non-structural Wood Treatment

Registered uses of chlorpyrifos for outdoor non-structural wood treatment (fence posts, utility poles, railroad ties, landscape timbers, logs, pallets, wooden containers, poles, posts, and processed wood products) were not restricted or cancelled under the agreement between the USEPA and the chlorpyrifos registrants, nor are these uses proposed for restriction or cancellation in the chlorpyrifos IRED. Chlorpyrifos contributions, if any, from wood treatment operations to nearby surface waters are not expected to change and could potentially serve as an ongoing source of chlorpyrifos to urban waterways.

Outdoor Use of Containerized Bait

Residential use of containerized bait will continue. Since the amount of active ingredient is small and the container is designed to limit environmental exposure, this continued use will not likely be an ongoing source of chlorpyrifos to urban waterways.

Indoor Urban Uses

Chlorpyrifos uses will be allowed, but are not subject to CDPR reporting requirements, inside ship holds, railroad boxcars, industrial plants, manufacturing plants (including treating of processed wood products), and warehouses with new end-use product labels listing the use of chlorpyrifos for these purposes only. Impact to surface water quality from these indoor sources is not likely to occur since there is likely no pathway to surface water from these indoor sources (Moran, 2001).

Table A-5 in Appendix A lists the potential for chlorpyrifos (associated with USEPA-allowed chlorpyrifos urban uses with the exception of containerized baits) in surface runoff to enter waterways. Outdoor uses of chlorpyrifos are more likely to affect surface water quality in urban waterways than indoor uses.

4. LINKAGE ANALYSIS

The man-made pesticides diazinon and chlorpyrifos that are detected in Sacramento urban creeks come from a combination of: 1) direct runoff from agricultural uses (very little in the urban portions of Sacramento County); 2) runoff from urban pest control applications (by licensed pest control operators); 3) runoff from unreported urban residential and landscaping applications (typically applied by homeowners); and, 4) direct deposition and runoff of atmospheric drift from any of the primary application sites (studies suggest that these sites are mostly agricultural dormant season applications). The linkages between the likeliest sources (urban runoff and agricultural transport/drift) and the levels of diazinon and chlorpyrifos detected in Sacramento County urban waterways are described.

4.1 Pesticides in Urban Runoff

The potential for diazinon and chlorpyrifos to migrate in runoff from the points of application in the urban environment and to discharge into surface waters has historically been high due to the widespread use of these pesticides in residential yards, around building perimeters, and on driveways, sidewalks and other impervious surfaces. Impervious surfaces have little microbial activity available to degrade these pesticides before they are carried by rainfall or irrigation (e.g., landscape and lawn watering) runoff and discharged to storm drains that lead to urban waterways. If pesticide application occurs just prior to a substantial storm (or irrigation) event, three or more times as much pesticide may runoff in comparison to runoff under dry conditions (Moran, 2001).

A Sacramento County urban runoff study from 1993 to 1995 showed that the residential catchment (Sacramento Sump 104) contained an average of at least two times the diazinon concentrations as compared to an industrial catchment (Sacramento Sump 111), with diazinon present in both catchments between October 1993 and May 1995. The highest concentrations occurred during August and September 1994. Very high diazinon concentrations were also present in the residential catchment in April 1994 and also in January and February 1994 and 1995, during the orchard dormant spray season (Bailey *et al.* 2000).

Four urban runoff monitoring sites in the city of Sacramento (three sumps - Sump 104, Sump 111 and Sump 152 - and a Sacramento County creek - Strong Ranch Slough) have been monitored since 1995. Monitoring results indicate that diazinon and chlorpyrifos concentrations in Sacramento County urban runoff often exceed the CDFG aquatic life protection criteria (Section 2.3). Urban runoff from drainage areas containing greater proportions of residential land use seems to contribute higher diazinon and chlorpyrifos concentrations. Diazinon and chlorpyrifos concentrations in Sacramento County urban runoff generally have been higher during storm events than during the dry season (Denton, 2001; Russick, 2001; see also Table 5-1).

Several urban runoff studies demonstrate that impervious surfaces facilitate the transport of diazinon and chlorpyrifos into urban waterways during rain events or from irrigation.

An urban runoff study conducted in 2001 for the Alameda County Flood Control and Water Conservation District demonstrated that the greatest amount of diazinon wash-off removal from concrete test plots occurred during the first one-quarter inch of runoff created by simulated heavy rainfall. The amount of diazinon wash-off rapidly declined during the next 1-inch of runoff. Variations of surface characteristics of individual test plots, the rate of initial diazinon application, and cumulative amounts of simulated rainfall influenced the wash-off rate. Diazinon concentrations in grab samples collected from puddles in paved areas near areas that were sprayed were similar in magnitude to those observed in runoff from test plots. In samples collected over 250 feet from the actual application sites, diazinon was detected and detections of diazinon continued to occur several months after application (Feng and Scanlin, 2001).

A study conducted in Alameda County, California in 1997 showed that the primary source of diazinon was urban storm water runoff, with residential areas also being a substantial source and with commercial and industrial areas potentially being important contributors. Runoff from densely developed sub-watersheds generally contained higher average diazinon concentrations than sub-watersheds receiving runoff from less densely developed urban areas (Scanlin and Feng, 1997). In the study, diazinon was applied according to label instructions to control ants on a residential property two days prior to a small storm event. Runoff samples were collected from the residential property during the small storm event and analysis of samples showed diazinon concentrations of up to 1,200 σg/L (Scanlin and Feng 1997). These results also suggest that diazinon concentrations in urban runoff from residential areas may be attributable to proper use, in accordance with label instructions, rather than attributable to improper disposal and over-application (Scanlin and Feng, 1997). Additional urban runoff studies found very high levels of diazinon in runoff collected from impervious surfaces, where all applied diazinon was removed during a simulated 0.98-inch (25 mm) storm (Moran, 2001). In Sacramento County, diazinon and chlorpyrifos are the two most commonly-used insecticides and they are also the most common insecticides detected at toxic levels in Sacramento County creeks (Russick, 2001). Based on these runoff studies, impervious surfaces facilitate the wash-off of diazinon and chlorpyrifos that can then be transported to Sacramento urban creeks.

A study by Cooper (1996) in the City of Palo Alto, California found that very small amounts of diazinon flushed into stormwater runoff can result in diazinon concentrations of 0.100 to 0.400 μg/L in urban creeks. The creeks studied were San Francisquito Creek, which is comparable in size to Arcade Creek, and Matadero Creek, which is comparable in size to Elk Grove Creek (Cooper, 1996).

Several studies found that about 1 percent of diazinon applied to turf occurs in runoff and that the amounts of active ingredient removed during runoff from turf and from agricultural sites are similar (Moran, 2001).

Direct applications of insecticides to surface waters and storm drains are less common, but potentially high amounts of insecticides applied to storm drains can be released to surface waters (Moran, 2001). Use of chlorpyrifos in sewer systems is still registered.

There are no permitted discharges of municipal wastewater effluent to the six impaired Sacramento County urban waterways included in this TMDL report. Therefore, use of chlorpyrifos in sewer systems is not considered to be a source of pesticides in the urban waterways.

4.2 Atmospheric Transport and Deposition of Pesticides

Fractions of pesticides applied in urban and agricultural settings become entrained in the atmosphere as aerosols or volatiles. Majewski and Capel (1995) found that organophosphorus compounds are often detected in air, rain and fog nationwide. The atmospheric pesticides can drift and be deposited via precipitation or fog onto urban outdoor surfaces and directly into waterways. Between spring and fall, these drift-deposited pesticides may be washed off over-watered lawns, gardens and impervious surfaces into storm drains and, subsequently, into Sacramento County urban creeks.

Several scientific studies of pesticides in the atmosphere in the United States and adjoining Canadian provinces determined that the atmosphere distributes and deposits pesticides far from where they were applied. The presence of pesticides in the atmosphere is frequently correlated to their regional agricultural use, with deviations usually correlated to non-agricultural (urban) use, environmental persistence, and sampling and analytical difficulties.

In the Sacramento Valley, high atmospheric pesticide concentrations occur on a seasonal basis such as during spring row crop planting when temperatures are warm, and also during winter months when dormant orchards are sprayed with pesticides (Majewski and Capel, 1995). Majewski and Baston (2002) suggest that urban use is the primary source of pesticides in waterways in the spring and summer and that agricultural use is the primary source during the winter.

One Central Valley experiment was conducted to determine the spray distribution, spray drift, and volatilization of diazinon during agricultural applications (using an air-blast sprayer) to a dormant peach orchard. The study found that diazinon was not distributed evenly between the trees and the soil in the orchard, based on the relative surface area of each. Rather, most of the diazinon was present on the soil (dissipating with a 19-day half life) and long-term volatilization losses were great in comparison to application drift losses. This experiment showed that most of the atmospheric diazinon in the Central Valley during the orchard dormant spray season resulted from volatilization with nearly all of the atmospheric diazinon occurring in the atmosphere in the vapor phase - primarily in rain and fog (Glotfelty *et al.* 1990a).

Another Central Valley study detected diazinon and chlorpyrifos and their oxons in fog mostly in January (Glotfelty *et al.* 1990b). Several transport mechanisms (dry deposition, rainfall and fog droplets - particularly when there is sufficient wind to blow the droplets to the ground) can cause inadvertent pesticide contamination of crops or outdoor urban surfaces (Glotfelty *et al.* 1990a).

Sieber and others (1993) conducted a study in the San Joaquin Valley in 1993 to assess airborne concentrations of four organophosphorus pesticides (chlorpyrifos, diazinon, parathion and methidathion) and air and fog deposition residues. Results of this study concluded that all four OP pesticides and their oxons were detected in fog water samples. Measurable residues of these four OP pesticides were also detected on parsley sentinel plants that were set out at the study site during the study period. Also, oxons of these four OP pesticides were measured in higher amounts in daytime samples versus nighttime samples (suggesting that photochemical oxidants were involved in oxon formation). Researchers determined that, because no significant OP dormant spray applications were made at the study site until later in the sampling period, airborne OP residues detected at the study site likely moved there by air transport from nearby orchards (1 km to 100 km away, or more). From this study, it was also determined that area-wide contamination of air with OP pesticides may be significant (Sieber *et al.*, 1993).

In 1996 and 1997, the USGS studied the atmospheric transport of pesticides in the Sacramento County metropolitan area by collecting composite bulk air samples and by measuring wind speeds and wind directions weekly at one urban and two agricultural locations (Majewski and Baston, 2002). A variety of pesticides were detected throughout the study period, though diazinon, chlorpyrifos and three other pesticides were detected most frequently and at the highest concentrations. Chlorpyrifos and diazinon were frequently detected at all three monitoring sites, particularly when the prevailing wind was from the south. Results from this study suggest that, during the winter, pesticides used in agricultural areas can become airborne and be transported into the urban environment. However, urban pesticide use during the same period makes determining the amount of pesticides transported from the agricultural environment into the urban environment difficult to quantify (Majewski and Baston, 2002). This study demonstrated during several sampling periods, usually in January and February, that upwind diazinon and chlorpyrifos concentrations in the atmosphere at one of the study's agricultural sites were higher than downwind diazinon and chlorpyrifos concentrations at the study's urban site (Majewski and Baston, 2002). Rain is suspected of being an important contributor of diazinon and chlorpyrifos to Sacramento County urban waterways, as the orchard dormant spray season coincides with the rainy season in the Sacramento valley (Bailey *et al.* 2000).

It should be noted that chlorpyrifos will strongly absorb to sediments (Koc = 6,070; Fawcett and Tierney, 2001) and diazinon will moderately absorb to sediments (Koc = 1,445; USDA, 1995). Therefore, some portion of the chlorpyrifos or diazinon in rainwater will absorb to sediment or grass before it reaches a stream. Trapping efficiencies of vegetated buffer strips are high for chlorpyrifos (about 60%-80%; Fawcett and Tierney, 2001) and give some indication of how much chlorpyrifos would be absorbed before reaching a stream. Due to the low organic content of impervious surfaces, little absorption of chlorpyrifos or diazinon is likely to occur from them.

The median diazinon concentrations for Sacramento metropolitan area rain samples and Arcade Creek rain samples during the 2000 dormant spray season exceed the 0.080 µg/L acute aquatic life protection criterion for diazinon (Table 4-1). The median diazinon concentration in Arcade Creek surface water during the same dormant period is nearly 3 times that of both Sacramento metropolitan area and Arcade Creek median rain concentrations. The median diazinon concentration in Arcade Creek during the dormant spray season is higher during "dry" days versus "wet" days (dry days have 0 inches rainfall as measured at Sacramento Municipal Airport; wet days have greater than 0 inches rainfall as measured at Sacramento Municipal Airport). This suggests that rain events dilute the concentrations of diazinon in the creek, while adding to the total diazinon loads in Arcade Creek. The higher diazinon concentrations in Arcade Creek during the dormant spray season (relative to the diazinon concentrations in rainwater), and differences between wet and dry days, suggest that local urban diazinon use is the source of higher diazinon concentrations in Arcade Creek.

In contrast to the diazinon pattern for wet and dry days during the dormant spray season, wet days have higher median concentrations than dry days, when the entire year is considered (see Table 5-1). This suggests that rainfall runoff is an important mechanism in delivering diazinon to the urban creeks, even when diazinon is not present in the rainfall.

The median concentrations of chlorpyrifos in rainfall and in Arcade Creek on wet and dry days are very similar. For chlorpyrifos, it does not appear that rainwater is providing much dilution nor does the presence of chlorpyrifos in rainwater appear to result in an increase in concentration levels in Arcade Creek. Although chlorpyrifos levels in rainwater are elevated, the concentrations in the creek appear to be the same whether the transport process is washoff from rainfall runoff or washoff due to irrigation runoff (assuming that creek concentrations on "wet" days represent rainfall runoff and that creek concentrations on "dry" days represent irrigation runoff). The primary source of chlorpyrifos in Arcade Creek is apparently washoff from the surrounding urban land surface though, as for diazinon, rainfall may contribute to the total chlorpyrifos load in Arcade Creek.

Table 4-1. Median Diazinon and Chlorpyrifos Concentrations in Rainfall and in Arcade Creek during the 2000-2002 Orchard Dormant Spray Season

	Rainfall		**Arcade Creek**	
Constituent	Median Concentration (µg/L) in Rainfall in Sacramento Metropolitan Area[1]	Median Concentration (µg/L) in Rainfall at Arcade Creek	Median Concentration (µg/L) in Arcade Creek at Watt Avenue -dry days-	Median Concentration (µg/L) in Arcade Creek at Watt Avenue -wet days-
Diazinon	**0.087** (n[2] = 40)	**0.083** (n = 21)	**0.295** (n = 7)	**0.240** (n = 17)
Chlorpyrifos	**0.028** (n = 29)	**0.023** (n = 10)	**0.026** (n = 3)	**0.026** (n = 7)

[1]Rainfall samples collected at Lincoln Airport, Arcade Creek, Herald (Spector and Harader, 2001; Denton, 2002 [diazinon only] personal comm., and Spector, 2002), and at Sumps 104 and 111 (Russick, 2001) in Sacramento, California.

[2] n = number of samples

Atmospheric transport of chlorpyrifos and diazinon from agricultural areas to Sacramento County urban watersheds is potentially an ongoing source for these pesticides in the urban creeks.

4.3 Projected Future Use of Diazinon and Chlorpyrifos in Sacramento County

Reported agricultural diazinon and chlorpyrifos usage rates for Sacramento County in 2000 were compared to the USEPA agricultural diazinon and chlorpyrifos use cancellations proposed in the 2002 Diazinon IRED and the 2001 Chlorpyrifos IRED (see Tables A-1 and A-2, Appendix A). Based on the comparison, future agricultural use of diazinon and chlorpyrifos in Sacramento County will likely occur at approximately 100 percent of the historic reported use rate. However, additional proposed use restrictions applicable to many crops (USEPA, 2002a and USEPA, 2001b) may reduce future agricultural diazinon and chlorpyrifos use. The proposed restrictions include: decreasing the maximum number of allowable agricultural applications; decreasing the maximum agricultural application rates; and controlling the types of agricultural diazinon applications (i.e. foliar and/or soil). It is not possible to quantify the effects the proposed agricultural diazinon and chlorpyrifos reductions will have, especially since the USEPA 2002 Diazinon IRED and the 2001 Chlorpyrifos IRED are interim documents that have not been finalized.

4.3.1 Diazinon

The total urban (non-agricultural) diazinon use (including reported and unreported use) within the Arcade Creek and Morrison Creek (including Elder and Elk Grove Creeks) watersheds in 2000 was approximately 6,200 pounds and 6,400 pounds, respectively. A substantial decline in urban use of diazinon is expected starting in 2003. The USEPA phase-out of indoor urban diazinon uses was completed in December 2002. By August 2003, diazinon products for outdoor urban uses could no longer be sold and outdoor urban diazinon product registrations will be canceled by December 31, 2004 (Table A-1, Appendix A) (USEPA, 2001a).

The USEPA diazinon phase-out will eliminate sales of diazinon-containing products for all indoor and outdoor urban diazinon uses, thus eventually eliminating the occurrence of urban sources of diazinon. The phase-out is expected to eventually result in the elimination of diazinon-related water quality impairments from urban application sources as people use up their diazinon-containing products.

The USEPA-mandated diazinon application restrictions for fruit and nut orchards in the Sacramento Valley could reduce the amount of diazinon available for atmospheric transport during the orchard dormant spray season. Future rain monitoring will need to be conducted to determine if diazinon concentrations in rain have decreased as a result of the USEPA urban-use phase-out and restrictions on some agricultural diazinon uses.

Within the Morrison Creek watershed (including Elder and Elk Grove creeks), diazinon was reportedly used primarily on pears and tomatoes and, to a smaller extent, on strawberries and at nurseries. These agricultural uses (within the Morrison Creek watershed) constitute nearly 88 percent of the total amount of diazinon reportedly applied on these crops in Sacramento County in 2000 (PUR, 2000).

Within the Arcade Creek watershed, strawberries were reportedly the only crop that received diazinon applications in 2000. These applications occurred in March and constituted 44 percent of the total diazinon reportedly applied to strawberries in Sacramento County in 2000 (PUR, 2000).

Although diazinon use on pears, tomatoes, strawberries, and at nurseries is allowed to continue (USEPA, 2002a; Parsons, 2002), the USEPA-proposed restrictions on agricultural application rates of diazinon and the number and types of applications for these crops (USEPA, 2002a) could considerably reduce the amount of diazinon available for transport, particularly during the rainy season. During the rainy months of 2000, diazinon use within the Morrison Creek watershed occurred at nurseries and on strawberries and pears. The only agricultural applications of diazinon that occurred within the Morrison Creek watershed outside the orchard dormant spray season occurred at nurseries, in mid-December 1999 and late March 2000, and in very small amounts (0.12 pounds). No diazinon applications on stonefruit and nut trees were reported in the Morrison Creek watershed in 1999 and 2000 (PUR, 1999-2000).

4.3.2 <u>Chlorpyrifos</u>

The total urban chlorpyrifos use (including reported and unreported use) within the Arcade Creek and Morrison Creek watersheds in 2000 was approximately 5,200 pounds and 5,400 pounds, respectively (PUR, 2000). Unlike the USEPA-mandated urban-use diazinon phase-out, the USEPA-mandated chlorpyrifos phase-out does not cancel all indoor and outdoor urban uses. Some indoor and outdoor urban chlorpyrifos uses are cancelled and several indoor and outdoor urban chlorpyrifos uses will be reduced (Table A-2, Appendix A) (USEPA, 2000c).

As stated previously (in Section 3), most indoor urban uses and all outdoor home lawn and most other outdoor residential uses were cancelled in December 2001. Chlorpyrifos use as a termiticide, which comprises a substantial portion of structural pest control chlorpyrifos use, will be completely phased out by the end of 2005 (USEPA, 2000c).

Urban chlorpyrifos uses still allowed by the USEPA are restricted in several ways: maximum application rates on golf courses, outdoor industrial sites, and road medians are reduced by 75 percent; chlorpyrifos applications for mosquito control and on fire ant mounds are to be applied by professional pest control applicators only; and containerized baits that contain chlorpyrifos active ingredient are the only residential chlorpyrifos uses allowed. Restricted urban chlorpyrifos uses are expected to further reduce chlorpyrifos residues on outdoor urban impervious surfaces, thereby reducing urban-derived chlorpyrifos residues in urban creeks. However, urban chlorpyrifos applications for outdoor non-structural wood treatments (fenceposts, utility poles, railroad ties, landscape timbers, logs, pallets, wooden containers, poles, posts, and processed wood products) and chlorpyrifos use on manhole covers and sewer systems (not in septic tank or storm drain systems) are allowed to continue without restrictions and could potentially affect urban creek water quality (USEPA, 2000c). Indoor use in ship holds, railroad box cars, warehouses, industrial plants, manufacturing plants, and food processing plants are allowed to continue without restrictions also, but are less likely to cause water quality impairments.

Reported chlorpyrifos applications on alfalfa and sugarbeets accounted for the majority of agricultural chlorpyrifos use within Sacramento County in 2000. Corn, walnuts, and nursery crops also received chlorpyrifos applications (CDPR PUR, 2000). Future chlorpyrifos use on alfalfa, corn, walnuts, and sugarbeets is allowed to continue with some restrictions (USEPA, 2001b). Chlorpyrifos use on nursery crops is allowed to continue without additional restrictions (USEPA, 2001b; Meyers, 2002).

During 2000, the majority of reported agricultural use of chlorpyrifos within the Morrison Creek watershed occurred on alfalfa and nursery crops (particularly on outdoor container/field grown plants)(PUR, 2000).

The USEPA-mandated chlorpyrifos use restrictions for fruit and nut orchards in the Sacramento Valley, including Sacramento County, should also reduce the amount of chlorpyrifos available for regional transport in rain during the orchard dormant spray season (USEPA, 2001b). In Sacramento County in 2000, the greatest agricultural chlorpyrifos use during the dormant spray season was on apples (186 pounds) and peaches (172 pounds) (PUR, 2000). Per the USEPA-mandated restrictions (USEPA, 2000c), chlorpyrifos use on apples is restricted for some dormant season applications. There are no restrictions or cancellations of chlorpyrifos use on peaches USEPA, 2000c and 2001b).

5. LOADING CAPACITY, ALLOCATION OF LOADS, AND MARGIN OF SAFETY

5.1 Loading Capacity

The TMDL can be expressed in terms of "…mass per time, toxicity, or other appropriate measure" (40 CFR § 130.2(i)). The relationship between diazinon and chlorpyrifos loads and concentration levels in Arcade Creek were evaluated by Denton (2001) and by Regional Board staff.[1] Denton studied timing of sample collection in relation to storm hydrographs and found a good correlation (R^2= 0.7115) between Arcade Creek flow and diazinon loads. Tables 5.1 and 5.2 compare median loads, flows, and concentrations during different times of year and wet versus dry days. In contrast to the trend shown in Figure 4-1 (in which diazinon concentrations were higher during dry days than during wet days during the dormant season), diazinon concentrations were higher during wet days than during dry days when looking at the entire year. The data in these tables indicates that concentration levels are not closely related to loads. There are some

[1] Arcade Creek at Watt Avenue was used since concentration and flow data were available, whereas, flow data was generally not available for other impaired waterbodies included in this TMDL report.

seasons when flows and loads have been low and concentrations have been high. There are also times when flows, loads, and concentrations are all relatively high.

Table 5-1. Median Flows and Diazinon Concentrations and Associated Loads in Arcade Creek at Watt Avenue from 1996 to 2001

WET & DRY DAYS		WET & DRY SEASONS[1]			
		Wet Season			
Wet Day	Dry Day	Pre-Dormant Spray Season (Nov-Dec)	Dormant Spray Season (Jan-Feb)	Post-Dormant Spray Season (Mar-May)	Dry Season (June-Oct)
Median Flow (cfs)[2]					
39.00	1.70	0.78	16.50	1.95	1.70
Median Diazinon Concentration (ng/L; n = number of samples)[3]					
370 (n = 31)	290 (n = 58)	318 (n = 12)	257 (n = 24)	442 (n = 20)	244 (n = 33)
Load (g/d)					
35.31	1.21	0.60	10.38	2.11	1.02

[1] Rain data from UCD IPM (2003). [2] Flow data from USGS (2003). [3] Concentration data from Domagalski (2000) and Russick (2001).

Table 5-2. Median Flows and Chlorpyrifos Concentrations and Associated Loads in Arcade Creek at Watt Avenue from 1996 to 2000

WET & DRY DAYS		WET & DRY SEASONS			
		Wet Season			
Wet Day	Dry Day	Pre-Dormant Spray Season (Nov-Dec)	Dormant Spray Season (Jan-Feb)	Post-Dormant Spray Season (Mar-May)	Dry Season (June-Oct)
Median Flow (cfs)					
39.00	1.60	1.00	14.00	4.00	1.00
Median Chlorpyrifos Concentration (ng/L; n = number of samples)					
36 (n = 17)	8 (n = 39)	29 (n = 8)	35 (n = 10)	8 (n = 17)	6 (n = 21)
Load (g/d)					
3.42	0.03	0.07	1.20	0.08	0.02

The load and concentration data for Arcade Creek are plotted in Figures 5.1 and 5.2 for diazinon and chlorpyrifos, respectively. As can be seen in these figures, there can be up to two orders of magnitude difference in loading for the same observed concentration. A regression analysis was performed which indicates that load and flow are weakly correlated ($R^2 = 0.11$ for diazinon and $R^2 = 0.14$ for chlorpyrifos).

Figure 5.1. Arcade Creek Diazinon Load vs Concentration

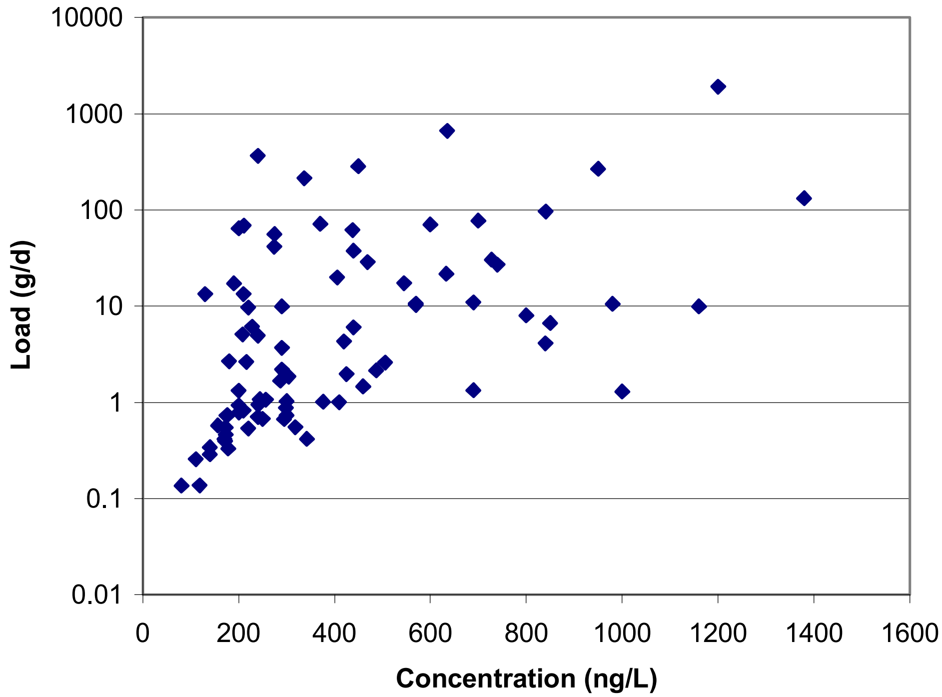
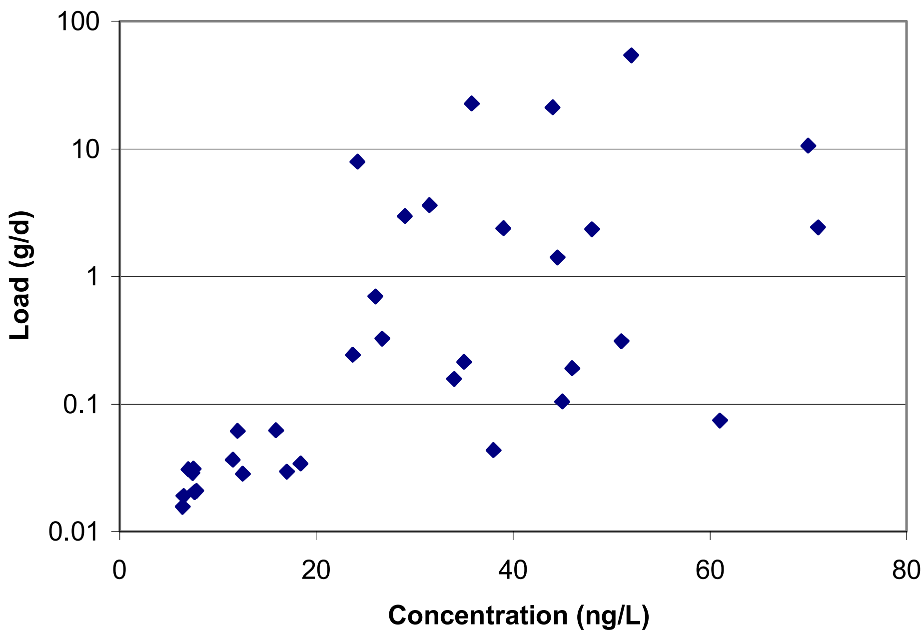


Figure 5.2. Arcade Creek Chlorpyrifos Load vs Concentration



Since there is not a clear, direct relationship between concentration levels and load for diazinon and chlorpyrifos in the urban creeks, a load-based TMDL might not be protective of aquatic life when concentrations are high but total loads are low.

A TMDL based on attaining the diazinon and chlorpyrifos water quality criteria established by CDFG was also considered. Under this scenario, diazinon or chlorpyrifos concentrations must not exceed the CDFG criteria in order to meet the TMDL. Such an approach would be appropriate if diazinon and chlorpyrifos were never present in an urban stream at the same time.

Since diazinon and chlorpyrifos can and do co-occur, the joint toxicity of these chemicals must be considered (CVRWQCB, 1998; pages IV-18.00 and IV-35.00). Therefore, it is recommended that a measurement of potential toxicity, rather than mass per time or another measure, be used to express the TMDL. The Loading Capacity (see Equation 2, below) is established so that the sum of the ratios of diazinon and chlorpyrifos concentrations in the stream to their respective criteria levels does not exceed one (1.0; in other words, the threshold for cumulative impacts to aquatic life cannot be exceeded).

$$\frac{C_{diaz}}{O_{diaz}} + \frac{C_{chlor}}{O_{chlor}} = S \qquad \text{[Equation 2]}$$

Where:

C_{diaz} = concentration of diazinon in the water body

O_{diaz} = diazinon criterion
= 0.080 µg/L (acute) 1-hour average
= 0.050 µg/L (chronic) 4-day average

C_{chlor} = concentration of chlorpyrifos in the water body

O_{chlor} = chlorpyrifos criterion
= 0.020 µg/L (acute) 1-hour average
= 0.014 µg/L (chronic) 4-day average

S = The sum, Loading Capacity. A sum exceeding one (1.0) indicates that the beneficial use may be impacted.

The recommended Loading Capacity is consistent with the narrative toxicity water quality objective which states, in part "…This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effect of multiple substances…" The Loading Capacity is also consistent with the pesticides narrative objective that states, in part "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses" (CVRWQCB, 1998; pages III-6.00 and III-8.00).

5.2 Allocations

As discussed above, the primary sources of diazinon and chlorpyrifos are urban areas, agricultural applications within Sacramento County and in surrounding areas, and rainwater and fog. If each of these sources does not exceed one when the cumulative impact for each source is calculated (from Equation 2), then the loading capacity will not be exceeded.

Waste load allocations and load allocations for sources containing both diazinon and chlorpyrifos are set at one toxic unit to reflect the additive toxicity of these pesticides. These allocations are calculated based on the CDFG aquatic life protection criteria using the additivity calculation described in Equation 2. The waste load and load allocations apply to potential (additive) combinations of diazinon and chlorpyrifos. Table 5-3 summarizes the various allocations.[2]

Table 5-3. Waste Load Allocations and Load Allocations for Diazinon and Chlorpyrifos in Sacramento County Urban Creeks[1]

Water Quality Criterion Type	Constituent	Criterion Value	Waste Load Allocations (for Point Sources) for all NPDES sources	Load Allocations (for Non-Point Sources) for agricultural sources and rainwater
Chronic[2]	Diazinon	50 ng/L	Less than, or equal to, 1.0	Less than, or equal to, 1.0
	Chlorpyrifos	14 ng/L		
Acute[3]	Diazinon	80 ng/L	Less than, or equal to, 1.0	Less than, or equal to, 1.0
	Chlorpyrifos	20 ng/L		

[1] The actual waste load or load is calculated using the appropriate criterion values and relevant diazinon and chlorpyrifos concentration data in Equation 2.
[2] Four-day average, not to be exceeded more than once every three years, on average
[3] One-hour average, not to be exceeded more than once every three years, on average

Allocation approaches that allowed one source to have a cumulative impact greater than one and other sources to have cumulative impacts less than one would also be possible. Such allocation scenarios could be developed if the relative contribution of each source was well known. Since the relative contribution of sources is not well known, it would be difficult to demonstrate that other allocation scenarios would not exceed the loading capacity.

[2] Note that if diazinon or chlorpyrifos occur without the other pesticide present, the formula yields a waste load allocation and a load allocation equal to the respective CDFG aquatic life protection criterion (numeric targets).

5.3 Margin of Safety

TMDL analysis involves uncertainty; therefore, a margin of safety is required for this TMDL. The margin of safety can be expressed implicitly, explicitly, or both. This TMDL includes an implicit margin of safety to account for uncertainty in the following two areas:

- ***Numeric Target*** - The proposed diazinon and chlorpyrifos concentration targets were selected mainly because they are the most protective of aquatic organisms. The chosen targets are the acute and chronic diazinon and chlorpyrifos water quality criteria developed by the California Department of Fish and Game.

- ***Linkage Analysis*** - The linkage between diazinon and chlorpyrifos allocations and the proposed numeric targets and toxicity targets is straightforward as the allocations equal the numeric targets. Equating the allocations to the numeric targets provides an implicit margin of safety, since the primary sources of diazinon and chlorpyrifos must be at or below the receiving water targets. Potential, unmeasured, sources of dilution flow (e.g. ground water or flow upstream of the urban area) are not taken into account in allocating the available assimilative capacity.

6. IMPLEMENTATION PLAN FOR THE TMDL

As discussed earlier in this report, the primary source of diazinon and chlorpyrifos in Sacramento area urban creeks appears to be from urban runoff. Therefore, this TMDL is being implemented through the NPDES Sacramento Municipal Separate Storm Sewer Systems Permit (Sacramento MS4 Permit/Permit) and associated monitoring and reporting program (Order No. R5-2002-0206; NPDES No. CAS082597).

Other potential sources of diazinon and chlorpyrifos to the urban creeks are considered to be minor. Since the Regional Board does not intend to regulate the minor sources based on this TMDL, a Basin Plan Amendment to adopt and implement this TMDL is not necessary. In addition, the Sacramento MS4 Permit (summarized below) contains the necessary provisions to implement this TMDL, so a Basin Plan Amendment would duplicate an existing Regional Board program.

The Sacramento Stormwater Program Permittees (Permittees) have jurisdiction over urban stormwater runoff in Sacramento County (including the Cities of Sacramento, Citrus Heights, Elk Grove, Folsom, Galt and Rancho Cordova). The Permittees are responsible for meeting the NPDES requirements, which include the requirement to reduce the discharge of pollutants in Sacramento County municipal storm water to the maximum extent practicable.

The Permit requirements include a number of provisions related to the presence of diazinon and chlorpyrifos. Finding 65 states that the Department of Fish and Game's diazinon and chlorpyrifos criteria will be used to assess the effectiveness of the phase out and the Permittee's pesticide reduction efforts. The receiving water limitations (B.1.m.) state that toxics (such as pesticides) cannot be at levels that adversely affect beneficial uses and the discharge cannot cause or contribute to a violation of the water quality standards (B1.o), including the Regional Board's toxicity and pesticide objectives.

The Permittees are required to conduct monitoring of receiving water, urban tributaries, urban discharges, and rain. Wet season and dry season monitoring will be conducted by the Permittees to measure the concentrations of a number of pollutants, including diazinon and chlorpyrifos. Toxicity testing is also required during the second year of the monitoring program. Toxicity identification evaluations are required for any samples that are substantially toxic to test organisms. Sales and use surveys are also required, which should allow tracking of products that are replacing diazinon and chlorpyrifos.

The Regional Board may also require the Permittees to prepare a Diazinon and Chlorpyrifos Mitigation Program to address any remaining urban sources that impair urban creeks. The Regional Board determines whether a Diazinon and Chlorpyrifos Mitigation Program is necessary based on the monitoring conducted under the permit. If the Mitigation Program is necessary, additional monitoring may be required to identify and quantify remaining urban sources of diazinon and chlorpyrifos.

The USEPA-mandated phase-out of diazinon and the phase-down of chlorpyrifos use in the urban environment is expected to eventually eliminate diazinon concentrations and substantially reduce chlorpyrifos concentrations in impaired Sacramento County waterways. As stated previously in this report, the USEPA-mandated phase-out first eliminated the uses of diazinon and chlorpyrifos that provide the greatest risk for exposure to children in the urban environment (home lawn, indoor crack and crevice, whole house 'post-construction' treatments, and schools and parks) and allowed the continuation of remaining diazinon and chlorpyrifos uses for a limited period of time. (Tables A-1 and A-2 in Appendix A list the phase-out/phase-down schedules for urban and agricultural registered uses of diazinon and chlorpyrifos.)

Sales of diazinon for use in the urban environment will be non-existent by the end of 2004. Remaining registered chlorpyrifos products for use in the urban environment (listed in Table A-5 in Appendix A) and some agricultural uses of diazinon and chlorpyrifos that can occur in urban areas (such as nurseries, mushroom houses, and greenhouses) are potentially ongoing sources in Sacramento County urban watersheds (Moran, personal comm., 2002). In addition, the aerial transport of diazinon and chlorpyrifos from agricultural areas, and subsequent deposition in the urban environment, may still occur.

If results from the monitoring conducted by the Sacramento Stormwater Program Permittees (during their 2003 to 2007 Permit cycle) indicate that the USEPA phase-out/phase-down of diazinon and chlorpyrifos does not resolve water quality impairments in the urban creeks, then additional controls or monitoring may be required of the Permittees. If other sources contribute to ongoing non-attainment of objectives, the

Regional Board may prepare a Basin Plan Amendment or take another action to address those sources of diazinon and chlorpyrifos.

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Appendix A

Table A-1. Diazinon Uses and USEPA Mitigation Measures

<table>
<tr><th>Sites of Use</th><th>USEPA Mitigation Measures</th><th>Effective Dates</th></tr>
<tr><td><u>Indoor Uses</u>

All uses inside any structure, vehicle, vessel, aircraft, or enclosed area and/or on any contents therein (except mushroom houses) including residences, food/feed handling establishments, schools, museums, stores, hospitals, sports facilities, warehouses, and greenhouses.

All indoor pet uses including pet collars.</td><td>USEPA Federal Register notice January 10, 2001:

Product registrations being canceled or amended to delete indoor uses from end use product labels, except in mushroom houses.</td><td><u>2/01</u>: Cancellation order

<u>3/1/01</u>: End use products for indoor uses no longer to be formulated with manufacturing use products

<u>12/31/02</u> Retailers stop sale of indoor use products containing diazinon.</td></tr>
<tr><td><u>Outdoor Non-Agricultural Uses</u>

Home lawn, garden, any other outdoor residential or outdoor non-agricultural uses</td><td>1. Production phase down

2. Uses phased out

3. Registrants buy back existing products from retailers

4. Product registrations expire/are canceled with no provision for existing stocks</td><td><u>By 2003</u>: Registrants reduce diazinon production by 50 percent or more
<u>6/30/03</u>: Stop formulation of products
<u>8/31/03</u>: Stop sale to retailers

<u>By 12/31/04</u>: Registrants buy back existing products from retailers

<u>12/31/04</u>: Product registrations canceled</td></tr>
</table>

Table A-1. Diazinon Uses and USEPA Mitigation Measures (continued)

Table A-1 Diazinon Uses (continued)		
Sites of Use	**USEPA Mitigation Measures**	**Effective Dates**
<u>Agricultural Uses</u>[1] **Crops** Alfalfa, Bananas, Beans (dried), Bermudagrass, Celery, Red Chicory (radicchio), Citrus, Clover, Coffee, Cotton, Cowpeas, Cucumbers, Dandelions, Kiwi, Lespedeza, Parsley, Parsnips, Peppers, Irish and Sweet Potatoes, Sorghum, Spinach, Squash (summer and winter). Strawberries, Swiss chard, Tobacco, Tomatoes, Turnips. **<u>Other Sites of Use and Domestic Animal Use</u>** Pastures, Rangeland, Sheep.	1/10/01: USEPA Federal Register notice of proposed deletion of uses from product labels.	**Proposed cancellations may be effective after 30-day public comment period, upon issuance of February 2001 cancellation order.**

Information extracted from USEPA Diazinon Revised Risk Assessment, January 2001and based upon the December 2000 USEPA and Diazinon Technical Registrants Memorandum of Agreement to cancel registrations for specific end use products containing the active ingredient diazinon.

1. USEPA will phase out and cancel certain additional crop uses and formulations of the organophosphate insecticide diazinon to reduce risks to birds and other wildlife, agricultural workers, and the environment. These actions are part of a second agreement between USEPA and diazinon technical registrants, reflected in the Diazinon Interim Reregistration Eligibility Decision (IRED) signed by the USEPA on July 31, 2002. During the next 2 to 5 years , the Diazinon IRED requires a number of measures to be phased in including: cancel nearly all granular uses; discontinue all aerial application; discontinue foliar application to nearly all vegetable crops; reduce number of applications per growing season for most uses; require engineering controls for mixers and loaders, and closed cabs for applicators; set re-entry intervals (REIs) at 2 to 18 days and cancel certain agricultural diazinon sites of use.

Table A-2. Chlorpyrifos Uses and USEPA Mitigation Measures

Sites of Use	USEPA Mitigation Measures	Effective Dates
Outdoor Residential Uses Home lawn and most other outdoor uses	-New end use products classified for restricted use or packaged in large containers (except for baits in child resistant packaging). -Use will be cancelled.	12/1/00: -Classification and/or large container packaging . -Stop formulation. 2/1/01: Formulators stop sale **12/31/01: Retailers stop sale**
Indoor Residential Crack and crevice and most other indoor uses	-New end use products classified for restricted use or packaged in large containers. -Use will be cancelled.	12/1/00: -Classification and/or large container packaging. -Stop formulation. 2/1/01: Formulators stop sale **12/31/01: Retailers stop sale**

Table A-2. Chlorpyrifos Uses and USEPA Mitigation Measures (continued)

Sites of Use		USEPA Mitigation Measures	Effective Dates
Termiticides		New end use products classified for restricted use or packaged in large containers. Limit use to 0.5 percent solution	12/1/00: -Classification and/or large container packaging. **-0.5 percent solution limit in label directions as of 12/1/00**
	----------------------- Full barrier (whole house) post-construction use	---------------------------- Use will be cancelled	----------------------------------- 12/1/00: Stop formulation 2/1/01: Formulators stop sale **12/31/01: Retailers stop sale**
	Spot and local post-construction	Use will be cancelled	**12/1/00: Stop formulation unless label lists stop use date of 12/31/02**
	Pre-construction	Use will be cancelled	12/31/04: Stop production **12/31/05: Stop use**

Table A-2. Chlorpyrifos Uses and USEPA Mitigation Measures (continued)

Sites of Use	USEPA Mitigation Measures	Effective Dates
Indoor Non-residential Uses Indoor areas where exposure to children is possible (such as schools)	Uses will be cancelled	12/1/00: Stop formulation 2/1/01: Formulators stop sale **12/31/01: Retailers stop sale**
Outdoor Non-residential Uses Outdoor areas where exposure to children is possible (such as parks)	Uses will be cancelled	12/1/00: Stop formulation 2/1/01: Formulators stop sale **12/31/01: Retailers stop sale**
All Agricultural Uses	New end use products classified for restricted use or packaged in large containers. New end-use products must bear revised Restricted Entry Intervals (REIs)	**As of 12-1-00** **As of 12-1-00**
Apples	Prohibit production of chlorpyrifos products labeled for post-bloom application(Production of pre-bloom, dormant application allowed only) Post-bloom use prohibited Tolerance lowered	8/00– 9/00 **12-31-00: Stop use**
Tomatoes Grapes	Production of products for use on tomatoes prohibited; Tolerances revoked & use cancelled ---------------------- Tolerances will be lowered	August-September 2000 **12-31-00: Stop use** **------------------------------**

Table A-2. Chlorpyrifos Uses and USEPA Mitigation Measures (continued)

REGISTERED NON-AGRICULTURAL USES OF CHLORPYRIFOS THAT REMAIN		
INDOOR		
Residential use of containerized baits	Already in child resistant packaging	**Use allowed to continue**
Use in ship holds, railroad boxcars, industrial plants, manufacturing plants, food processing plants (Indoor areas where children will not be exposed.)	**Continue use at current rate**	**12-1-00: New end-use product labels must list only these uses**
OUTDOOR		
Golf courses	Reduce maximum application rate from 4 pounds per acre to 1 pound per acre	
Road Medians	Reduce maximum application rate from 4 pounds per acre to 1 pound per acre	
Industrial Plant Sites	Reduce maximum application rate from 4 pounds per acre to 1 pound per acre	
Non-structural wood treatments: fencepost, utility poles, railroad ties, landscape timbers, logs, pallets, wooden containers, poles, posts, and processed wood products	**Continue use at current rate**	
Public Health Uses Fire ant mounds (drench and granular treatment) Mosquito control	 For professional use only For professional use only	
Manhole Covers[1]	Use not allowed on manhole covers in storm drain systems	**9-01: New end-use product labels prohibit this use**

Information extracted from USEPA Chlorpyrifos Revised Risk Assessment, June 2000 and based upon the June 7, 2000 USEPA and Chlorpyrifos Technical Registrants Memorandum of Agreement to cancel registrations for specific end use products containing the active ingredient chlorpyrifos.
1. Source: USEPA Chlorpyrifos IRED, 2001 (USEPA, 2001b).

Table A-3. Sacramento County 2000 Agricultural Diazinon Use & Estimated Future Sacramento County Agricultural Diazinon Use^

Crops Reportedly Grown In Sacramento County in 2000	Diazinon Applications During 2000												Total Pounds of Diazinon Applied in Sacramento County in 2000	% Diazinon use (by crop) of total 2000 diazinon use in Sacramento County	% Diazinon use (by crop) estimated to continue in Sacramento County
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
ALMOND^												225.00	225.00	5.37	5.37^
APPLE^		20.15	58.00	0.15								0.25	78.55	1.87	1.87^
APRICOT^		0.50										0.50	1.00	0.02	0.02^
BEANS (All or Unspecified)						0.15							0.15	0.00	0.00
BEETS, GENERAL													0.00	0.00	0.00
CANTALOUPE													0.00	0.00	0.00
CHERRY^		123.00											123.00	2.93	2.93^
CHRISTMAS TREE PLANTATIONS													0.00	0.00	0.00
COLLARDS													0.00	0.00	0.00
CORN, HUMAN CONSUMPTION													0.00	0.00	0.00
CUCUMBER (PICKLING, CHINESE, ETC.) *													0.00	0.00	0.00
GRAPES and GRAPES, WINE													0.00	0.00	0.00
KALE													0.00	0.00	0.00
MELONS^													0.00	0.00	0^
MUSTARD, GENERAL													0.00	0.00	0.00
NECTARINE^		3.00		2.25	0.47							2.20	7.92	0.19	0.19^
N-GRNHS GRWN CUT FLWRS OR GREENS						0.25							0.25	0.01	0.01
N-GRNHS GRWN PLANTS IN CONTAINERS													0.00	0.00	0.00
N-GRNHS GRWN TRNSPLNT/PRPGTV MTRL													0.00	0.00	0.00
N-OUTDR CONTAINER/FLD GRWN PLANTS			0.12				9.68					0.01	9.81	0.23	0.23
ONIONS (GREEN)													0.00	0.00	0.00
PEACH^		5.00		2.25	2.83							2.20	12.28	0.29	0.29^
PEAR^		0.40		240.4					60.00	2007	1124	0.50	3432.70	81.91	81.91^
PEPPERS (FRUITING VEGETABLE), (BELL,CHILI, ETC.) *													0.00	0.00	0*
PLUM (INC. WILD PLUMS FOR HUMAN CONSUMPTION)^		1.55		0.55	0.70							2.20	5.00	0.12	0.12^

Table A-3. Sacramento County 2000 Agricultural Diazinon Use & Estimated Future Sacramento County Agricultural Diazinon Use^ (continued)

Crops Reportedly Grown In Sacramento County in 2000	Diazinon Applications During 2000												Total Pounds of Diazinon Applied in Sacramento County in 2000	% Diazinon use (by crop) of total 2000 diazinon use in Sacramento County	% Diazinon use (by crop) estimated to continue in Sacramento County
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
RADISH													0.00	0.00	0.00
SQUASH (ALL OR UNSPEC) *													0.00	0.00	0*
STRAWBERRY (ALL OR UNSPEC)^			10.49	1.00					2.00				13.49	0.32	0.32^
SUGARBEET, GENERAL													0.00	0.00	0.00
SWISS CHARD (SPINACH BEET)*													0.00	0.00	0*
TOMATO				113.3	0.08								113.38	2.71	2.71
TOMATOES, FOR PROCESSING/CANNING			9.96	158.33									168.29	4.02	4.02
WALNUT (ENGLISH WALNUT, PERSIAN WALNUT)													0.00	0.00	0.00
WATERMELONS													0.00	0.00	0.00
TOTAL DIAZINON USED PER MONTH	**0**	**154**	**79**	**518**	**4**	**0**	**10**	**0**	**62**	**2007**	**1124**	**233**	**4191**	**99.99**	**99.99**

2000 Sacramento County diazinon use data (which is preliminary data) was obtained from the DPR Pesticide Use Report Database, 2000.

Highlighted crops were reportedly grown and harvested in Sacramento County in 2000 and received one or more diazinon applications for which future diazinon applications are no longer allowed, per the 2002 USEPA Diazinon Interim Reregistration Eligibility Decision (IRED).

*Diazinon use for these crops only allowed for Special Local Needs as listed on Section 24 C Special Local Need Labels.

^ Future diazinon applications allowed but limited by number of applications, type of application and/or application rates, per the 2002 USEPA Diazinon IRED. These USEPA limits will reduce agricultural diazinon use in Sacramento County from 2000 use levels, at undetermined amounts, but potentially below the 100% projected future agricultural diazinon use for Sacramento County.

Diazinon uses for crops that are not marked or highlighted were not assigned application restrictions by USEPA in 2002; therefore, diazinon application allowances remain unchanged.

Table A-4. Sacramento County 2000 Agricultural Chlorpyrifos Use & Estimated Future Sacramento County Agricultural Chlorpyrifos Use^

Crops Reportedly Grown in Sacramento County in 2000	Chlorpyrifos Applications During 2000												Total Pounds Applied in Sacramento County in 2000	% Chlorpyrifos use (by crop) of total 2000 chlorpyrifos use in Sacramento County	% Chlorpyrifos use (by crop) estimated to continue in Sacramento County
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
ALFALFA (FORAGE - FODDER) (ALFALFA HAY)			1373	91.92			142.86	104.68					1712.46	29.63	29.63
APPLE*	186.03	70.01	66.14		139.50	126.60							588.28	10.18	5.09*
ASPARAGUS (SPEARS, FERNS, ETC.)								640.58					640.58	11.08	11.08
CORN, HUMAN CONSUMPTION & CORN (FORAGE - FODDER)^							419.78	60.40					480.18	8.31	8.31^
N-GRNHS GRWN PLANTS IN CONTAINERS								0.11					0.11	0.00	0.00
N-GRNHS GRWN TRNSPLNT/PRPGTV MTRL													0.00	0.00	0.00
N-OUTDR CONTAINER/FLD GRWN PLANTS	1.57		3.46	7.13	0.98	8.25	6.08	8.91	3.29	2.75	4.09	4.81	51.32	0.89	0.89
N-GREENHOUSE GROWN CUT FLOWERS OR GREENS													2.00	0.03	0.03
PEACH	172.02												172.02	2.98	2.98
PEAR								55.67					55.67	0.96	0.96
RADISH													0.00	0.00	0.00
SORGHUM/MILO GENERAL^													0.00	0.00	0^
STRAWBERRY (ALL OR UNSPEC)													0.00	0.00	0.00
SUDANGRASS (FORAGE - FODDER) (SORGHUM SUDANESE)						0.50	375.26		150.18				525.94	9.10	9.10
SUGARBEET, GENERAL^						55.75	828.86	151.63	106.67				1142.91	19.78	19.78^
SUNFLOWER, GENERAL^													0.00	0.00	0^
WALNUT (ENGLISH WALNUT, PERSIAN WALNUT)^					5.98	7.98	52.03	341.94					407.93	7.06	7.06^
TOTAL CHLORPYRIFOS USED PER MONTH	**360**	**70**	**1443**	**99**	**146**	**199**	**1825**	**1364**	**260**	**3**	**4**	**5**	**5779**	**100.00**	**94.91**

2000 Chlorpyrifos use data (which is preliminary data) obtained from the DPR Pesticide Use Report Database, 2000.

*Post-bloom applications of chlorpyrifos prohibited as of 12/31/00 per the USEPA 2000 Chlorpyrifos Revised Risk Assessment and USEPA agreement with chlorpyrifos technical registrants.

Chlorpyrifos applications on apples during pre-bloom dormant periods are still allowed, but at lowered tolerances.

(Chlorpyrifos applications on tomatoes cancelled as of 12/31/00 and tolerances revoked and chlorpyrifos applications allowed on grapes at reduced tolerances, per the USEPA 2000 Chlorpyrifos Revised Risk Assessment and USEPA agreement with chlorpyrifos technical registrants. Use of chlorpyrifos on tomato and grape commodity crops reportedly did not occur in Sacramento County in 2000.)

^ Future chlorpyrifos applications allowed but limited by number of applications, type of application and/or application rates, per the 2001 USEPA Chlorpyrifos IRED. These USEPA limits will reduce chlorpyrifos use in Sacramento County from 2000 use levels, at undetermined amounts, but potentially below the 95% projected future chlorpyrifos use for Sacramento County.

Chlorpyrifos uses for above unmarked crops were not assigned application restrictions by the USEPA; therefore, chlorpyrifos uses remain unchanged.

Table A-5. Chlorpyrifos Urban Sites of Use Likely to Cause Water Quality Impairment After Implementation of USEPA Agreements with Technical Registrants

<table>
<tr><th colspan="4">Table A-5
Chlorpyrifos Urban Sites of Use Likely to Cause Water Quality Impairment After Implementation of USEPA Agreements with Technical Registrants</th></tr>
<tr><th>USEPA Designation for Chlorpyrifos Use Allowed</th><th rowspan="2">Corresponding CDPR Site Code And Site Name</th><th colspan="2">Potential for Surface Runoff</th></tr>
<tr><th>OUTDOORS</th><th>Very Likely</th><th>Less Likely</th></tr>
<tr><td>Manhole Covers</td><td>65026- Sewage Systems (Septic Tanks, Sewers, etc.)</td><td>X</td><td></td></tr>
<tr><td rowspan="2">Road Medians</td><td>67004- Highway Rights of Way (Roadways, Curbs, etc.)</td><td>X</td><td></td></tr>
<tr><td>67012- Private Roads, Walkways, Lanes, Patios, etc.</td><td>X</td><td></td></tr>
<tr><td>Mosquito Control
(by public health agencies only)</td><td>68502- Mosquito Abatement Districts</td><td>X</td><td></td></tr>
<tr><td>Golf Courses</td><td>33007- Turf, Golf Course (Fairways, Greens, Rough)</td><td>X</td><td></td></tr>
<tr><td>Industrial Plant Sites</td><td>67009- Industrial Sites (Lumber Yards, Tank Farms, etc.)</td><td>X</td><td></td></tr>
<tr><td>Non-structural wood treatment to include fence posts, utility poles, railroad ties, landscape timbers, logs, pallets, wooden containers, poles, posts, and processed wood products</td><td rowspan="3">64003-Wood Protection-Finished Wood Products;

64500-Wood Protection Treatments (all or unspecified);

64501- Lumber (Seasoned/Unseasoned);

97005- Wood Surfaces (Seasoned/Unpainted)</td><td rowspan="2">X</td><td rowspan="2"></td></tr>
<tr><td>INDOORS</td></tr>
<tr><td>Processed wood products treated during the manufacturing process at the manufacturing site or at the mill</td><td></td><td>X</td></tr>
<tr><td>Industrial Plants, Manufacturing plants</td><td>67009- Industrial Sites (Lumber Yards, Tank Farms, etc.)</td><td></td><td>X</td></tr>
<tr><td>Ship Holds</td><td>70004- Ships, Boat Premises, etc. (All or Unspecified)</td><td></td><td>X</td></tr>
<tr><td>Railroad Boxcars</td><td>70026- Railway Trains (All or Unspecified)</td><td></td><td>X</td></tr>
<tr><td>Warehouses</td><td>77004- Commercial Storages or Warehouses
(All or Specified)</td><td></td><td>X</td></tr>
</table>

Table A-5. Chlorpyrifos Urban Sites of Use Likely to Cause Water Quality Impairment After Implementation of USEPA Agreements with Technical Registrants (continued)

USEPA Designation for Chlorpyrifos Use Allowed	Corresponding CDPR Site Code and Site Name	Potential for Surface Runoff	
		Very Likely	Less Likely
INDOORS			
Food Processing Plants	71000-Food Processing/Handling Plant/Area (All/Unspecified) 71001- Bakeries, Bakery Equipment, etc. 71002- Bottling Plants (includes beverage bottles) 71003- Breweries, Distilleries, Beer Beverage Cases, etc. 71004- Canneries and Frozen Food Plants 71006- Feed Mills, Feed Stores, Feed Processing Plants 71008- Meat Processing Plants (Slaughter Houses, etc.) 71010-Wineries, Wine Cellars 71011- Flour Mills, Four/Grain Elevators, etc. 71012- Egg Processing Plants, Egg Breaking Plants 71019- Beverage Processing Plants, etc (All or Unspec.) 71022- Fish and Sea Food Processing Plants and Equip. 71033 & 71501- Food Processing/Handling Plant/Area (Food Area) 71502- Food Processing/Handling Plant/Area (Nonfood Area)		X

Information in Table A-5 derived from *Diazinon & Chlorpyrifos Products: Screening for Water Quality Implications, May 15, 2001* and from personal communication with author, Kelly D. Moran, Ph.D.