MEMORANDUM

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SUBJECT: **ASSESSMENT OF THE RELATIVE CONTRIBUTION OF STORMWATER RUNOFF TO DIAZINON AND CHLORPYRIFOS CONCENTRATIONS IN WATERS IDENTIFIED AS TOXIC HOT SPOTS OR 303(D) IMPAIRED**

This technical memorandum was prepared to fulfill the requirements of Section II. E. 6 of the Monitoring and Reporting Program (MRP) for the Sacramento Stormwater Quality Partnership (Partnership) National Pollutant Discharge Elimination System (NPDES) permit (Permit) for urban runoff in the Sacramento urban area. The Permittees are required to determine the relative contribution of diazinon and chlorpyrifos in Sacramento urban runoff discharged to water bodies within that jurisdiction that are either identified as a toxic hot spot (per Section 13394 of California Water Code) or are on the Federal Clean Water Act (CWA) 303(d) impairment list.

This assessment can be made using available urban load modeling data, pesticide rainfall data, and upstream non-urban load assumptions. The estimates of relative concentration derived in this analysis are intended to determine if the contribution of urban runoff to impairment is negligible. These estimates should not be used as the basis for other load derivation efforts or cited for purposes other than assessing relative contributions of (urban vs. non-urban) sources within Sacramento County. In some cases, the urban tributary watersheds extend outside of Sacramento County. These areas outside of the county are not considered in this analysis. This analysis does not consider whether the "listed" urban tributaries are actually impaired for the downstream beneficial uses that are applied to them by the Central Valley Regional Water Quality Control Board (Regional Board) for the purposes of the Permit.

Background

The Sacramento Stormwater Partnership last performed a "Target Pollutant Prioritization" in March 2001, which identified chlorpyrifos and diazinon as the two highest ranked constituents. Since the beginning of 2005, diazinon is no longer

available to consumers and is only used in controlled and regulated agricultural applications. A phase-out of chlorpyrifos began in 2001 and is now only available for regulated agricultural uses. The California Department of Pesticide Regulation (DPR) estimated the 2003 Sacramento County application of diazinon and chlorpyrifos as 10,165 lbs. and 8,389 lbs., respectively. This 2003 annual mass of diazinon and chlorpyrifos was applied to 3,141 acres and 3,740 acres of agricultural crops, respectively. Both pesticides have relatively low (soil) adsorption coefficients and would tend to stay dissolved in water rather than accumulating in sediments or on dry soil. Chemical properties of these constituents pertinent to this relative loading estimate are shown in Table 1. Biological and photolytic degradation may be the most significant fates of these pesticides in the environment.

Table 1. Selected Chemical Properties of Diazinon and Chlorpyrifos

Chemical Property	Diazinon	Chlorpyrifos
Water Solubility (Avg, mg/L)	60.0	1.39
Adsorption Coefficient (Koc)	1,581	125.2
Hydrolysis Half-life (Avg, Days)	138.0	58.1
Aerobic Soil Half-life (Avg, Days)	40.0	113.3

The Regional Board has previously adopted an organophosphorus (OP) pesticide total maximum daily load (TMDL) for urban tributaries in Sacramento.[1] The TMDL document provides substantial documentation of available data and previous OP pesticide studies in the area. The Partnership also previously performed a Calfed-grant funded OP Pesticide Toxicity Control Project that included intensive monitoring of OP pesticides in Arcade Creek, the Sacramento River, and the American River. Fifteen monitoring events were completed between May 1999 and May 2000. The Partnership continues a number of permit-required and additional investigative OP pesticide monitoring and assessment programs including, urban runoff quality characterization, urban tributary monitoring, American and Sacramento river monitoring, rainfall monitoring, toxicity monitoring, and urban runoff load modeling. In 2005, the Partnership updated an urban runoff loading model to consider the most recent urban runoff characterization data[2]. The statistical model calculates bulk loading of specific constituents of interest, and assumes all constituents are conservative.

All of the "listed" urban tributaries in the "permitted" Sacramento area are shown in Table 2.

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[1] CVRWQB. *Total Maximum Daily Load Report for the Pesticides Diazinon and Chlorpyrifos in: arcade Creek, Elder Creek, Elk Grove Creek, Morrison Creek, Chicken Ranch Slough, and Strong Ranch Slough.* July 2004.

[2] Armand Ruby Consulting in association with Larry Walker Associates. *Sacramento Urban Runoff Discharge Characterization 2005* Prepared for the Sacramento Stormwater Quality Partnership. August 2005

Table 2. Sacramento Urban Tributaries with Impairment Listings for Organophosphorus Pesticides

Urban Tributary	Listing Type	OP Pesticide
Arcade Creek	303(d)	diazinon, chlorpyrifos
Chicken Ranch Slough	303(d)	diazinon, chlorpyrifos
Elder Creek	303(d)	diazinon, chlorpyrifos
Elk Grove Creek	303(d)	diazinon
Elder Creek	303(d)	diazinon, chlorpyrifos
Morrison Creek	303(d), Section 13394	diazinon
Natomas East Main Drain	303(d)	diazinon

Loading Assessment

The loading estimates for pesticides were based on distributional characteristics of pesticide concentrations in the entire watershed (i.e., all three urban runoff locations were grouped together) for use in a Monte Carlo simulation that "fed" into a continuous simulation of hourly rainfall for the 1970-2000 period. Other constituents contained multiple linear regression (MLR) models of concentration (e.g., concentration vs. days since last rainfall, total event rainfall, etc.) instead of the Monte Carlo representation. Regression models could not be used for diazinon and chlorpyrifos because there were too few detected data points to develop statistically significant regressions. Runoff quantity was simulated in the (30-year) continuous simulation using the observed hourly rainfall, actual sub-watershed land use designations, and imperviousness estimates. The hourly load estimates were summed for each year and all sub-watersheds. The total annual loads in wet and dry weather Sacrament urban (area) runoff for diazinon and chlorpyrifos were 77 and 6.1 pounds, respectively.

Although the non-urban (agricultural and open space) areas, are not included in the modeling effort, these loads can be estimated using the same concentration results and modifying the runoff volume using the non-urban areas and runoff coefficients. This concentration assumption has not been verified, however, one would expect that on an annual basis the total load *applied* to agricultural fields is greater, and more so now that these OP pesticides are banned for residential use. These loads are generally upstream of the urban tributaries. Upstream loads from outside of Sacramento County are not specifically considered here. There are also significant agricultural areas in the southern part of Sacramento County that are not within the watersheds assessed in this analysis.

The final source of OP pesticides in urban tributaries considered in this analysis is from atmospheric (wet) deposition. As part of their Permit, rainwater samples have been collected for analysis of OP pesticides at two locations in Sacramento County, one inside the urban area (Sump 104, Fruitridge and South Land Park), and one outside of the urban area (Prairie City). Samples were collected in 2003/04 and 2004/05 with 10 events coordinated with the Regional Board TMDL monitoring during that same period. A total of 14 events were sample by the Partnership during these two monitoring

seasons. Atmospheric deposition of OP pesticides in the Sacramento area has been studied by USGS[3] and the Regional Board[4,5]. The wet deposition sampling coordinated by the Regional Board with the Permittees targeted the dormant spray season (January through early February depending on weather conditions) and immediately following the dormant spray season. The Permittee-initiated wet deposition monitoring in Sacramento County generally detected diazinon and chlorpyrifos more frequently at the Sump 104 (urban) location than at the Prairie city (non-urban) location. Both constituents were detected in Sump 104 wet deposition 36% of the time. Summary statistics were generated for Sump 104 using a "regression on order statistics" (ROS) methodology. There were insufficient data to perform this analysis on the Prairie City results. Table 3 summarizes the output results from the ROS.

Table 3. Regression on Order Statistics Estimate of Sump 104 Wet Deposition Pesticide Concentration Summary Statistics

	Diazinon	Chlorpyrifos
Number of Samples (n)	14	14
Percent Detected (%)	35.7	35.7
Estimated Mean (µg/L)	0.065	0.033
Estimated Std. Dev. (µg/L)	0.070	0.026
Estimated Median (µg/L)	0.043	0.026
Maximum Detected Value (µg/L)	0.23	0.11

The average annual rainfall at the Sacramento Post office gage between 1970-2000 was 19.6 inches (median = 18.0 inches). The total urban area in Sacramento County determined from the Department of Conservation Farmland Mapping and Monitoring Program is 160,000 acres with an overall area-weighted impervious fraction of 0.52 (runoff coefficient of 0.518). These average values were used to calculate an order-of-magnitude estimate of the total wet deposition in a year in the urban area for diazinon (24 lbs/year) and chlorpyrifos (12 lbs/year). Application of these pesticides peaks during the dormant spray period which generally coincides with the highest regional precipitation period. The estimate chlorpyrifos wet deposition load exceeds the total estimated runoff load by a factor of two, but Atmospheric deposition does appear to be a significant source of OP pesticides within urban runoff.

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[3] Majewski, Michael S. and Baston David S., U.S. Geological Survey. *Atmospheric Transport of Pesticides in Sacramento, California, Metropolitan Area, 1996.1997.* 2002 Water Resources Investigation Report 02-4100. Prepared in cooperation with California State Regional Water Quality Control Board and California Department of Pesticide Regulation.

[4] CVRWQCB. *Concentrations of Pesticides in Sacramento Metropolitan Area Rainwater and Creeks during the 2001, 2002 and 2003 Orchard Dormant Spray Seasons.* 2004

[5] CVRWQCB. *Concentrations of Pesticides in Sacramento Metropolitan Area Rainwater during the 2004Orchard Dormant Spray Season.* 2005

A summary of the loading estimates for each of the "listed" urban tributaries is provided in Table 3. These estimates are intended for use only as an initial determination of whether urban runoff can be considered a negligible contribution to urban tributary OP pesticide loads, and is not expected to characterize the loads closer than an order of magnitude. The loads in Table 4 were calculated using the methodologies discussed above.

Table 4. Pesticide Load Estimates for Urban and Non-urban Land Uses and Wet Deposition in Sacramento County

Urban Tributary:	Arcade Creek	Chicken Ranch Slough	Elder Creek	Elk Grove Creek	Morrison Creek	Natomas East Main Drain	Strong Ranch Slough
Total Watershed Area (ac)	20,281	3,612	12,584	4,053	56,890	35,447	6,446
Downstream Point	Arcade at Watt	At Strong Ranch Slough	At Morrison Creek	At Morrison Creek	At Elder Creek	At Sac. R. Excluding Arcade Creek above Watt	At Chicken Ranch Slough
Urban Acres	19,844	3,399	3,333	2,237	10,622	22,247	4,446
% Urban Area (ac)	98%	94%	26%	55%	19%	63%	69%
Composite Urban Runoff Coefficient	0.54	0.59	0.60	0.63	0.49	0.47	0.59
DIAZINON							
Urban Runoff Load (lb/year) [1]	14.7	2.7	2.7	1.9	7.2	14.8	3.5
Non-Urban Runoff Load (lb/Year) [2]	0.036	0.017	0.76	0.15	3.9	1.1	0.16
Urban Wet Deposition Load (lb/year) [3]	3.1	0.57	0.57	0.40	1.5	3.0	0.75
Non-Urban Wet Deposition Load (lb/year) [3]	0.34	0.059	0.058	0.039	0.18	0.39	0.077
CHLORPYRIFOS							
Urban Runoff Load (lb/year) [1]	1.0	0.18	0.18	0.13	0.51	1.1	0.24
Non-Urban Runoff Load (lb/Year) [2]	0.0025	0.0012	0.051	0.010	0.27	0.079	0.011
Urban Wet Deposition Load (lb/year) [3]	1.6	0.29	0.29	0.20	0.76	1.5	0.38
Non-Urban Wet Deposition Load (lb/year) [3]	0.17	0.030	0.03	0.020	0.093	0.20	0.039

Notes:
•LOADING ESTIMATES APPROPRIATE FOR USE AS RELATIVE COMPARISONS ONLY
•Water area within Sacramento area considered. For those watersheds xtending outside of the County, actual watershed loads will be higher,
[1] Urban runoff loads taken from Sacramento Urban Runoff Discharge Characterization 2005.
[2] Non-urban runoff (upstream) loads estimated using non-urban area, 0.06 runoff coefficient, and converting average annual urban loads.
[3] Wet deposition loads esstimated using average annual rainfall, average concentration, and watershed area.

Conclusions

- The loading estimates indicate that the contribution from urban runoff to the impairment-listed Sacramento urban tributaries cannot be shown to be negligible compared to other sources (upstream and wet deposition) at this time. These urban tributaries are still listed as toxic hot spots or 303(d) impairments. However, the relatively recent restrictions on diazinon and chlorpyrifos in California, and the management programs initiated by the Partnership will likely continue to decrease the concentrations of these two OP pesticides in urban runoff.
- The contribution from upstream (non-urban) sources is significant and will likely continue to increase relative to urban loads as legacy supplies of "urban use" diazinon and chlorpyrifos are used up.
- The contribution from wet deposition is significant, and will likely increase relative to urban runoff as application loads are now more biased toward the regulated agricultural spraying.
- Continued monitoring of smaller sub-watersheds (Elk Grove Creek, Elder Creek, Chicken Ranch Slough, etc.) does not provide additional information to loading and impact assessments.

Recommendations

- Use analytical laboratories capable of lower reporting limits to better characterize OP pesticide concentrations.
- Continue or initiate upstream monitoring of at least one urban tributary with a significant upstream agricultural watershed.
- As required in the Permit, the assessment that was completed and discussed in this memorandum should be repeated annually and incorporate new information and analysis improvements. Potential improvements include verification of runoff quantity models, upstream monitoring in key watersheds, lower analytical concentration reporting limits, improved modeling of wet deposition characteristics (e.g., regression models), trend analysis, and more thorough review and use of other loading studies.
- Reduce the frequency or eliminate monitoring of sub-watersheds that provide redundant data and focus resources on longer term characterization efforts.