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STUDY 299, Ambient and Mitigation Monitoring in Urban Areas in Northern California

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1.0 INTRODUCTION

In highly urbanized areas of California there is high pesticide use. As tracked by the California Department of Pesticide Regulation (CDPR), licensed applicators apply over 4 million pounds (active ingredient) of pesticides in the largest metropolitan areas of California, vastly surpassing fourfold the urban pesticide use in less urbanized areas of the state (CDPR, 2013a). This use does not account for individual homeowner applications, which has been estimated to account for over 70% of the total urban pesticide use (UP3 Project, 2007). With this high volume of pesticide use, there is potential for pesticide runoff into urban creeks and rivers via storm drain systems. Numerous pesticides used in urban areas have been detected in urban creeks and rivers at concentrations that may be toxic to sensitive aquatic organisms (Budd et al., 2015; Weston and Lydy2014; Ensminger et al., 2013; Gan, 2012).

In response to the high level of urban pesticide use, CDPR's Surface Water Protection Program (SWPP) has monitored urban pesticide runoff since 2008 (He, 2008). A major portion of this work has been to determine the pesticides in urban runoff in targeted monitoring in northern and southern California. In this work, 39 different pesticides have been detected, with bifenthrin, imidacloprid, fipronil, 2,4-D, dicamba, triclopyr, and diuron being the most frequent detections. Of these, bifenthrin and fipronil are of most concern to aquatic organisms; their detections frequently exceed US EPA aquatic life benchmarks (Budd et al., 2015; Ensminger et al., 2013). With this monitoring, the SWPP has long term monitoring sites in northern and southern California. Long term monitoring sites allow for determining temporal and spatial pesticide runoff trends. For example, new surface water regulations were implemented in July 2012 with the intent of reducing pyrethroid runoff into urban surface waters (CDPR, 2013b). Long term monitoring sites help determine the effectiveness of these regulations.

A second major undertaking for the SWPP has been to measure the effectiveness of best management practices implemented by local municipalities to mitigate urban runoff. Municipalities in California are charged with developing and implementing a storm water management plan to reduce the discharge of pollutants (including pesticides) to the "maximum extent practicable" (Cal/EPA, 2015). Such programs include outreach and education, as well as best management practices to curtail runoff. Outreach programs have been developed to increase consumer awareness (Sacramento Stormwater Quality Partnership, 2012; UC IPM Online, 2014; Our Water – Our World, 2015), but success of these programs to reduce pesticide runoff is unknown. On the other hand, best management practices as constructed wetlands have good potential to reduce pesticide runoff and their efficacy has been documented (Budd, 2011). The

city of Folsom, California requires new development projects to minimize stormwater runoff by integrating stormwater quality treatment controls into the design of the project (City of Folsom, 2015a; Sacramento Stormwater Quality Partnership, 2012). The SWPP has been monitoring the effectiveness of two constructed water quality treatment ponds (CWQTP) in Folsom built for reducing urban runoff from residential areas. Some reduction of pesticide runoff has been observed in these ponds but the data is inconclusive due to lack of pesticide loading data (Budd et al., 2013a). Pesticide loads into and out of these CWQTPs have not been documented due to incomplete flow measurements at the outfall. Recently, flow gauging equipment has been installed at the Marsh Hawk CWQTP through contract 13-C0052 with UC Davis (http://cdpr.ca.gov/docs/emon/surfwtr/contracts/ucdavis_13-C0052.pdf). With flow gauging stations at the inputs and outfall of this CWQTP, we can better evaluate the efficacy of the CWQTP to reduce pesticide loading into surrounding receiving surface waters.

Study 299 is a continuation of CDPR's urban monitoring in northern California, with some changes to monitoring frequency, site locations, and pesticides of interest for analysis. Data from this study will be used to evaluate urban pesticide water quality trends. The main study objective is to determine the detection frequency of specific pesticides and their concentrations at various urban monitoring sites in northern California. A second objective will be mitigation focused; to determine the efficacy of CWQTPs in Folsom to reduce pesticide runoff into receiving waters.

2.0. OBJECTIVES

For Study 299, the objectives are:

1) Determine the presence and concentrations of selected pesticides in urban storm water and dry-weather runoff at stormdrain outfalls in Roseville and Folsom;
2) Determine the presence and concentrations of selected pesticides in surface waters (including creeks and rivers in the Sacramento area [Folsom, Roseville, Rancho Cordova, Elk Grove, and the City and County of Sacramento] and in the San Francisco Bay area (Dublin, Pacheco, and San Jose);
3) Evaluate the effectiveness of CWQTPs to reduce pesticides from storm water and dry-weather urban runoff;
4) Determine the toxicity of water samples at long term monitoring locations, using toxicity tests conducted with *Hyalella azteca*;
5) Evaluate the effectiveness of CDPR's surface water regulation Section 6970 through long term (multi-year) monitoring at selected sampling locations;
6) Evaluate the magnitude of measured concentrations relative to water quality or aquatic toxicity thresholds.

3.0 PERSONNEL

The study will be conducted by staff from the CDPR's Environmental Monitoring Branch, Surface Water Protection Program, under the general direction of Kean S. Goh, Ph.D., Environmental Program Manager I (Supervisory). Key personnel are listed below:

- Project Leader: Michael Ensminger, Ph.D.
- Field Coordinator: Kevin Kelley
- Reviewing Scientist: Robert Budd, Ph.D.
- Statistician: Dan Wang, Ph.D.
- Laboratory Liaison: Sue Peoples
- Analytical Chemistry, water: Center for Analytical Chemistry, California Department of Food and Agriculture (CDFA)
- Analytical Chemistry, sediment: California Department of Fish and Wildlife
- Collaborator: Lorence Oki, Ph.D., University of California at Davis, CE Assistant Specialist, Landscape Horticulture, Department of Environmental Horticulture, Phone: (530) 754-4135, Email: lroki@ucdavis.edu

Please direct questions regarding this study to Michael Ensminger, Senior Environmental Scientist (Specialist), at (916) 324-4186 or michael.ensminger@cdpr.ca.gov.

4.0 STUDY PLAN

4.1 Monitoring sites. We will conduct ambient monitoring in the Sacramento and San Francisco Bay areas. In the Sacramento area, four long term monitoring sites have been established in Roseville at three stormdrain outfalls and at one downstream sampling site in the Pleasant Grove Creek Watershed (Figure 1). The Roseville sites have been sampled since 2008 (2009 for pyrethroids), providing a baseline for observing trends. Also in the Sacramento area, Arcade Creek will be monitored at Norwood Avenue (Figure 2). This site was added in 2014 and numerous pesticides have been detected (11 pesticides detected of 23 monitored). To increase spatial distribution, four sites in the San Francisco Bay area will be monitored, in Pacheco (GRY030), Dublin (MCC040), and San Jose (Guad_TRM, COY060) (Figure 3). All sites were monitored in FY2014-2015; sites GRY030 and MCC040 were also monitored in 2008 – 2010. See Appendix 1 for site details.

Mitigation monitoring will be conducted in Folsom at two different CWQTPs. At one CWQTP, (Marsh Hawk Road; Figure 4), two stormdrain outfalls provide input from urban neighborhoods to supply the CWQTP. These outfall sites also have been used to determine long term trends; FOL2 has been monitored since August 2009 and FOL3 has been monitored since 2011 for selected analytes. Water and sediment will be collected at the Marsh Hawk CWQTP. At the second CWQTP (Natoma Station Drive), only sediment will be collected. Efficacy of the CWQTPs will be determined by mass loading differences at the inlets and outlet (Marsh Hawk) and by comparisons between calculated sediment toxicity units differences between the inlets and outlet (both CWQTPs).

One additional site in Folsom (FOL100) will be monitored to support bioassessment contract 13-C0029 with UC Davis (http://cdpr.ca.gov/docs/emon/surfwtr/contracts/ucdavis_13-C0029.pdf; Figure 5).

The surrounding drainage area of all stormdrain outfalls monitored (PGC010, PGC021, PGC022, FOL2, FOL3, TRP1) consist of single family dwellings, parks, and schools. The surrounding drainage area of all receiving waters (PGC040, ARC_Nor, GRY030, MCC040, COY060, Guad_TRM) consist of single and multiple family dwellings, parks, schools, golf courses, and light commercial buildings.

4.2 Monitoring Candidates. Pesticides selected for ambient water monitoring were from the results of a SWPP model to assist in prioritizing pesticides for monitoring in California surface waters. This model is based on current use patterns and aquatic toxicity benchmark data; the output is presented as a relative prioritization score (Budd et al., 2013b; Luo et al., 2014). Sites in Roseville are used to determine long term trends in pesticides detections in surface water; as such, these sites get a larger number of pesticides monitored. The below listed criteria were used to select pesticides for Roseville. These criteria were also used for Arcade Creek (Sacramento County) to ease logistics for sampling in the Sacramento area.

	Criteria	Number of pesticides	
		Roseville sites	Arcade Creek
1.	Use Score ≥ 2 (excluding Rights of Way)[1]	70	63
2.	"TRUE" recommendation	52	50
3.	Final Score ≥ 9 (based on chronic toxicity)	23	24

[1]Roseville is located in Placer County but pesticide use likely mimics use in Sacramento. Both counties are used for prioritization. For Arcade Creek, monitoring priority was limited to Sacramento County.

Twenty-three pesticides met the criteria for the Roseville sites (Appendix 2) and 24 pesticides met the criteria for Arcade Creek (Appendix 3). Other pesticides may also be monitored if the selected pesticides are present in the CDFA's analytical screens. Some selected pesticides may not have a CDFA analytical method available and therefore will not be monitored until a method becomes available. For the San Francisco Bay area (sites GRY030, MCC040, COY060, and Guad_TRM), monitoring will be limited due to resource limitations at the CDFA chemical lab. For these sites, only pyrethroids and fipronil (plus degradates) (Appendix 4) will be monitored based on the following criteria:

	Criteria	Number of pesticides
1.	Tox Score ≥ 5 for Alameda, Contra Costa, and Santa Clara Counties (excluding Rights of Way)[1]	37
2.	"TRUE" recommendation	30
3.	Final Score ≥ 15 (based on chronic toxicity)	7

[1]Tox score can range from 1 – 8. Due to limited analytical resources, only higher ranking pesticides (≥ 5) will be considered for the San Francisco Bay area.

At the mitigation monitoring sites (FOL2, FOL3, FOL5) different criterion was used. To ensure that we can observe differences between the inlets and outlet, we will only monitor pesticides that have had a historical detection frequency of ≥ 25% at these sites. Thus, we will monitor specifically for bifenthrin, (93% detection frequency [DF]), 2,4-D (81% DF), dicamba (36% DF), imidacloprid (34% DF), fipronil (32% DF), permethrin (30% DF), triclopyr (29%), and cyfluthrin (25%) (these pesticides had previously been chosen based on the priority model). Evaluating these pesticides also give good range of LogP values (PPDB, 2015), which may influence the effectiveness of their removal in the CWQTP (Appendix 5).

At the bioassessment site (FOL100) we will monitor the same pesticides as the mitigation sites in Folsom.

4.3 Water sampling. Roseville sites will be sampled four times during the year (two dry season events and two rainstorm events). Dry season events will take place in August and in June (Table 1). The rainstorm events will occur in October – November (the first flush rainstorm of the water year, if possible) and in the winter of 2015 (February – March). Arcade Creek and the San Francisco Bay area sites will be monitored for only one dry season sampling event (in August) and during one early season rain storm event (Table 2).

The Folsom sites at the Marsh Hawk CWQTP will be sampled four times during the year. However, we will sample one dry event (in June) and three rain storm events to take advantage of the use of flow-weighted samples through contract 13-C0052, and because dry flow runoff is quite reduced due to California's current drought. Dry runoff flow-weighted samples cannot be collected and therefore only mass loading can be determined during flow-weighted rain storm sampling. Rain storm event sampling will coincide with the rainstorm event sampling in Roseville, with the addition of a spring rain storm event (Table 3).

Most water samples will be collected as grab samples directly into 1-L amber bottles (Bennett, 1997). Where the stream is too shallow to collect water directly into these bottles, a secondary stainless steel container will be used to initially collect the water samples. At sites FOL2, FOL3, FOL5, and FOL100, water samples may be collected as a composite sample using automated sampling equipment, especially during rainstorm events (Sisnernoz et al., 2012). Samples will be stored and transported on wet ice or refrigerated at 4°C until analyzed. At least 10% of the field samples will be field blanks or field duplicates.

During some of the monitoring, water will be collected from a subset of the sampling sites and sent to the University of Davis, Aquatic Health Program, to be tested for toxicity to *Hyalella azteca*. The Roseville long term monitoring sites will be the main focus for toxicity testing. In addition, water samples will be collected at FOL2, FOL3, FOL5, and FOL100 as a courtesy to support bioassessment contract 13-C0029 with UC Davis.

4.4 Sediment sampling. Sediments will be collected up to three times a year at up to eight sampling sites in Roseville and Folsom (Table 4). Sediments will be collected using passive sampling techniques where practical, but substituting 1-quart Mason glass jars with 1-quart stainless steel AirScape® (http://planetarydesign.com) containers (Budd et al., 2009). Otherwise, sediments will be collected with stainless steel scoops from the top bed layer (Mamola, 2005).

Sediments will be sieved through at 2-mm sieve to remove gravel and plant material. Sediments will be analyzed for pyrethroids.

4.5 Field measurements. Water physiochemical properties (dissolved oxygen, electrical conductivity, pH, turbidity, and temperature) will be measured *in situ* during all grab sampling events with a calibrated YSI EXO 1 multiparameter water quality sonde (https://www.ysi.com/productsdetail.php?EXO1-Water-Quality-Sonde-89). Where feasible, flow rates will be estimated with a Global portable velocity flow probe (Goehring, 2008) or by the bucket method (Appropedia, 2012). At FOL 2, FOL3, and FOL5 flow rates will be determined by using a Hach Sigma 950 flow meters (Sisnernoz et al., 2012).

4.6 Sample Transport. CDPR staff will transport samples following the procedures outlined in CDPR SOP QAQC004.01 (Jones, 1999). A chain-of-custody record will be completed and accompany each sample.

4.7 Organic carbon and suspended sediment analysis. CDPR staff will analyze water and sediment samples for total organic carbon (TOC) using a TOC-V CSH/CNS analyzer (Shimadzu Corporation, Kyoto, Japan) (Ensminger and Goh, 2011; Ensminger, 2013a). Water samples will also be analyzed for suspended sediment (Lisker and Goh, 2010; Ensminger, 2013b).

4.8 Modifications for FY14 -15. The current sampling plan is an extension of urban monitoring in Northern California conducted during fiscal years 2010-2014 (for details of previous sampling protocols, see http://www.cdpr.ca.gov/docs/emon/pubs/protocol.htm for Study 269). The sampling and analysis schedule is similar to that for FY 2014-2015. Main differences include changes in the sampling schedule in Folsom, increased analytes collected at Arcade Creek (ARC_Nor), sampling in the San Francisco Bay area and at Arcade Creek during a rain event, and reducing the analytes collected in San Francisco Bay area (Table 5).

5.0 CHEMICAL ANALYSIS

The Center for Analytical Chemistry, California Department of Food and Agriculture, Sacramento, CA (CDFA) will conduct the pesticide analysis for water samples. CDFA will analyze eight different analyte groups which will include 35 pesticides and degradates (Table 6). The California Department of Fish and Wildlife (CDFW) will conduct pesticide analyses for eight pyrethroids in sediment (Table 7). Laboratory QA/QC will follow CDPR guidelines and will consist of laboratory blanks, matrix spikes, matrix spike duplicates, surrogate spikes, and blind spikes (Segawa, 1995). Laboratory blanks and matrix spikes will be included in each extraction set.

6.0 DATA ANALYSIS

All data generated by this project will be entered to a Microsoft Office Access database that holds field information, field measurements, and laboratory analytical data. All ambient monitoring analytical data will also be uploaded into the CDPR Surface Water Database (SURF) (http://cdpr.ca.gov/docs/emon/surfwtr/surfdata.htm).

Initial analysis of urban monitoring data has shown that the data is heavily skewed and contains numerous non-detects often with different reporting limits (RL) which may violate the normality and equal variance assumptions of the parametric procedures (e.g., ANOVA and *t*-tests) (Ensminger et al., 2013). The non-normal structure posits a violation of the normality assumption of the commonly-used parametric procedures (tests based on the estimate of mean and standard deviation). Although some parametric procedures may be robust to the normality assumption, the use of these procedures on non-normal data will still lead to bias and low power. In addition, the substitution of non-detections can result in inaccuracy of estimate and test result (Helsel, 2012). The presence of non-detections and multiple RLs limits the application of some widely-used parametric procedures, such as analysis of variance (ANOVA) and *t*-tests. While some other parametric procedures, such as the censored regression by using maximum likelihood estimate (MLE), are capable of handling censored data with multiple RLs, the validity of their results depends on the selection of correct distribution. In other words, the procedure is not distribution free and may lose power if the data does not follow a specific distribution.

In order to appropriately address the aforementioned characteristics of the sample data, a more generic and distribution-free approach, non-parametric statistics, will be used in this study. Helsel (2012) illustrated the application of non-parametric procedures to skewed and censored environmental data. We will primarily reference his book as a general guideline for data analysis of this study. The data will be analyzed by using R statistical program (http://www.r-project.org/), the Nondetects And Data Analysis for environmental data (NADA) package for R (http://cran.r-project.org/web/packages/NADA/NADA.pdf), and/or Minitab (http://www.minitab.com/en-us/).

Based on the study objectives, preliminary analysis, and data availability, we propose the following statistical procedures for data analysis (Table 8):

1) Explanatory data analysis will be performed to summarize the characteristics of the sample data. Urban monitoring data has been collected since 2008 for a variety of analytes (i.e., fipronil, 2,4-D, etc.; Table 6) at multiple locations (i.e., Folsom, Roseville, Sacramento, and San Francisco Bay; Appendix 1) with different site types (i.e., stormdrain outfalls and receiving water), and between different seasons (i.e., dry and wet seasons). Plots, such as boxplots, histograms, probability plots, and empirical distribution functions, will be produced to explore any potential patterns implied by the data;
2) Hypothesis tests will be conducted to compare the concentration between groups of interest. For example, we will test whether or not there is significant difference in concentration between the dry and wet season, or between the different locations. Non-parametric procedures will be used to compute the statistics for hypothesis test. For data with multiple reporting limits, it will be censored at the highest limit before proceeding if the test procedure allows only one RL;
3) Trend analysis will be included to depict the change in concentration over time. We are specifically interested in determining the effectiveness of CDPR regulation 6970 which went into effect July 19, 2012 to mitigate pyrethroid contamination in urban waters. The ambient monitoring data from the Roseville sites and from FOL2 and FOL3 will be used. For the trend analysis, we will use Akritas-Thenil-Sen non-parametric regression which regresses the censored concentration on time, or the Kaplan-Meier method, which tests the effects of year, month and location by developing a mixed linear model between the censored concentration and the spatial-temporal factors.

Finally, we will attempt to develop statistical models to assess the factors potentially impacting pesticide concentration in surface water. One possible attempt is to develop a logistic regression model to estimate and predict the likelihood of detection or exceedance. The response variable will be the probability of the concentration being greater than or equal to the RLs or the toxicity benchmark. A series of explanatory variables will be examined, including: rainfall, field measurements (e.g., flow rate, pH, water TOC, sediment TOC, and TSS), number of households drains water into the storm drain outfall/creek, residential density (percent of impervious areas), season, year, regulation, and so on. Further literature review will be conducted to identify possible explanatory variables in favor of the model.

7.0 TIMETABLE

Field Sampling:	July 2015 – June 2016
Chemical Analysis:	July 2015 – December 2016
Summary Report:	March 2017
SURF Data	June 2017

8.0 LABORATORY BUDGET

The cost for the CDFA chemical analyses of water samples for ambient monitoring is $113,400: $92,340, $10, 260, and $10,800 for Roseville, Sacramento, and the San Francisco Bay area, respectively (Table 9). Mitigation monitoring costs are $34,260 and the cost for bioassessment monitoring is $4,980. Most of this cost will be covered by the SWPP Mitigation BCP ($32,370) (R. Budd, personal communication). The difference between the monitoring/bioassessment costs and Mitigation BCP will be covered by the northern California ambient monitoring budget in lieu of addition ambient monitoring. For CDFW chemical analysis (sediment samples), the total cost is $12,517 (Table 4); this funded supplied through contract 10-C0116. All costs are estimated and include field QC sample analysis (field blanks and field duplicates) but not laboratory QC.

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Table 1. Ambient monitoring schedule and analytical cost estimates for water samples collected in Roseville, California, FY 2015-2016 and analyzed by CDFA.

Site	Analyte Group*	Dry Season Monitoring Events§		Rainstorm Monitoring Events§			QC Field samples	Total Number Samples	Cost/ Sample	Cost	Total Cost
		Ag 15	Ju 16	S-N 15	F-W 15/16	W 16					
		---------- Number of Samples ----------									
	CF	4	4	4	0	4	2	18	$540	$9,720	
	CY	4	4	4	0	4	2	18	$480	$8,640	
PGC010	FP/OP	4	4	4	0	4	2	18	$840	$15,120	
PGC021	IMD	4	4	4	0	4	2	18	$600	$10,800	
PGC022	DN short	4	4	4	0	4	2	18	$840	$15,120	
PGC040	PX	4	4	4	0	4	2	18	$690	$12,420	
	PY-6	4	4	4	0	4	2	18	$600	$10,800	
	TR short	4	4	4	0	4	2	18	$540	$9,720	
Roseville Total								144			$92,340

*CY = carbaryl; CF = chlorfenapyr; FP = fipronil + degradates; OP = organophosphates (chlorpyrifos, diazinon, and malathion); IMD = imidacloprid; DN = dinitroaniline herbicides + oxyfluorfen (short screen); PX = synthetic auxin herbicides; PY-6 = pyrethroid (six analyte screen); TR = photosynthetic inhibitor herbicides + norflurazon (short screen).

§Ag 15, August 2015; Ju 16, June 2016; S-N 15, September, October or November 2015; F-W 15/16, Fall or winter 2015-2016; W 16, Winter 2016. Dry season runoff has been reduced due to mandatory water rationing by the City of Roseville (2015). Alternate dates may be selected if monitoring sites are dry during scheduled sampling dates.

Table 2. Ambient monitoring schedule and analytical cost estimates for water samples collected in Sacramento and the San Francisco Bay Area, California, FY 2015-2016 and analyzed by CDFA.

Site	Analyte Group*	Dry Season Monitoring Events§		Rainstorm Monitoring Events§			QC Field samples	Total Number Samples	Cost/ Sample	Cost	Total Cost
		Ag 15	Ju 16	S-N 15	F-W 15/16	W 16					
		---------- Number of Samples ----------									
Arc_Nor (Arcade Cr)	CF	1	0	1	0	0	0	2	$540	$1,080	
	CY	1	0	1	0	0	0	2	$480	$ 960	
	DN Short	1	0	1	0	0	0	2	$840	$1,680	
	FP/OP	1	0	1	0	0	0	2	$840	$1,680	
	IMD	1	0	1	0	0	0	2	$600	$1,200	
	PX	1	0	1	0	0	0	2	$690	$1,380	
	PY-6	1	0	1	0	0	0	2	$600	$1,200	
	TR short	1	0	1	0	0	0	2	$540	$1,080	
Sacramento Sub-total											$10,260
GRY030 MCC040 GUA020 COY060	FP	4	0	0	4	0	1	9	$600	$5,400	
	PY-6	4	0	0	4	0	1	9	$600	$5,400	
San Francisco Bay Area Sub-total											$10,800
Arcade Creek and San Francisco Bay Area Totals								30			$21,060

*CY = carbaryl; CF = chlorfenapyr; FP = fipronil + degradates; OP = organophosphates (chlorpyrifos, diazinon, and malathion); IMD = imidacloprid; DN = dinitroaniline herbicides + oxyfluorfen (short screen); PX = synthetic auxin herbicides; PY-6 = pyrethroid (six analyte screen); TR = photosynthetic inhibitor herbicides + norflurazon (short screen).

§Ag 15, August 2015; Ju 16, June 2016; S-N 15, September, October or November 2015; F-W 15/16, Fall or winter 2015-2016; W 16, Winter 2016. Dry season runoff has been reduced due to mandatory water rationing by the City of Sacramento (2015), Santa Clara Valley (SCVWD 2015), Dublin (DSRSD 2015), and Pleasant Hill (CCWD 2015). Alternate dates may be selected if monitoring sites are dry during scheduled sampling dates.

Table 3. Monitoring schedule and analytical cost estimates for mitigation monitoring and bioassessment water samples collected in Folsom, California, FY 2015-2016 and analyzed by CDFA.

Site	Analyte Group*		Dry Season Monitoring Event§	Rainstorm Monitoring Events§			Well Samples‡	QC Field samples	Total Number Samples	Cost/ Sample	Total Cost
			June 16	S-N 15	W 16	Sp 16					
			---------- Number of Samples----------								
Mitigation	FP		3	3	3	3	1	1	13	$600	$8,400
FOL2	IMD		3	3	3	3	0	1	13	$600	$7,800
FOL3	PX		3	3	3	3	1	1	13	$690	$9,660
FOL5	PY-6		3	3	3	3	1	1	13	$600	$8,400
Bioassessment	FP		0**	0**	1	1	0	0	2	$600	$1,200
	IMD		0**	0**	1	1	0	0	2	$600	$1,200
FOL100	PX		0**	0**	1	1	0	0	2	$690	$1,380
	PY-6		0**	0**	1	1	0	0	2	$600	$1,200
Totals									72	--	$39,240

*FP = fipronil + degradates; IMD = imidacloprid; PX = synthetic auxin herbicides; PY-6 = pyrethroid (six analyte screen).

§Ju 16, June 2016; S-N 15, September, October or November 2015; W 16, Winter 2016; Sp, Spring 2016. Dry season runoff has been reduced due to mandatory water rationing by the City of Folsom (2014b). Alternate dates may be selected if monitoring sites are dry during scheduled sampling dates.

‡Well samples are obtained from within the CWQTP do determine movement through the soil layer

**Only water for toxicity testing for contract 13_C0029 (http://cdpr.ca.gov/docs/emon/surfwtr/contracts/ucdavis_13-C0029.pdf) will be collected. USGS will be collecting water for chemical analysis at these sampling dates.

Table 4. Monitoring schedule and analytical cost estimates for sediment samples collected during FY 2015-2016, and analyzed by CDFW. All samples analyzed for pyrethroids.

Sampling Period	Sites	No. of Samples	Cost per Sample[§]	Cost	Grand Total
Fall 2015 after first flush rain fall	PCC010, PGC019*, PGC040, FOL2, FOL3, FOL5, TRP1, TPR2	8	$596.05	$4,768.40	
Winter 2014	FOL2, FOL3, FOL5	3	$596.05	$1,788.15	
Spring 2014	PCC010, PGC019*, PGC040, FOL2, FOL3, FOL5, TRP1, TPR2	8	$596.05	$4,768.40	
Field duplicates (various timing)	Selected sites	2	$596.05	$1,192.10	$12,517.05

*A combination of PGC021 and PGC022

[§]$45 per sample + 31% overhead

Table 5. Modifications for Study 299, monitoring in northern California. Listed below are modifications from FY 14-15 Study 269 protocol (http://www.cdpr.ca.gov/docs/emon/pubs/protocol/study269protocol2014_15.pdf).

Change from FY 2014-2015	Justification
Change water monitoring in Folsom (FOL2, FOL3, FOL5, FOL100) from two dry season and two rain events to one dry season event and three rain events	Limited runoff due to drought; flow weighted samples can only be collected during rain events, which makes better use of contract 13-C0052
Change the pesticides sampled at Arcade Creek (ARC_Nor) to include, carbaryl, chlorfenapyr, organophosphates, and dinitroaniline and synthetic auxin herbicides	Pesticide selection based on priority program for Sacramento County
Replace norflurazon with tebuthiuron in photosynthetic inhibitor herbicide screen	Based on priority model results for Sacramento County
Change sampling timing at Arcade Creek and in the San Francisco Bay area from two dry sampling events to one dry and one rain storm sampling event	Limited runoff and detections in dry event sampling in FY14-15; historically increased detections during rain events
Monitoring in the San Francisco Bay Area limited to pyrethroids and fipronil (plus degradates)	Limited analytical resources; only most toxic pesticides monitored
No sediment collection prior to first flush rain event	Limited runoff due to drought

Table 6. Chemical analysis of pesticides in the northern California urban monitoring Study 299. The California Department of Food and Agriculture (CDFA) will analyze all water samples. Specific methods can be found at http://www.cdpr.ca.gov/docs/emon/pubs/em_methd_main.htm.

Pesticide	Analyte Screen (Method ID)	Method Detection Limit (µg L^{-1})	Reporting Limit (µg L^{-1})
Carbaryl	Carbaryl (CY) (EMON-SM11.3)	0.0111	0.05
Chlorfenapyr	Chlorfenapyr (CF) (EMON-SM-05-033)	0.0624	0.1
Fipronil	Fipronil (FP) + Organophosphate (OP) (EMON-SM-05-013)	0.004	0.05
Fipronil sulfide		0.003	0.05
Fipronil sulfone		0.005	0.05
Fipronil desulfinyl		0.003	0.05
Fipronil desulfinyl amide		0.005	0.05
Fipronil amide		0.005	0.05
Diazinon		0.0012	0.01
Chlorpyrifos		0.0079	0.01
Malathion		0.0117	0.04
Imidacloprid	Imidacloprid (IMD)	0.0101	0.05
Bifenthrin	Pyrethroid (PY-6) (EMON-SM-05-022)	0.00176	0.005
Cyfluthrin		0.00173	0.015
Cypermethrin		0.00175	0.015
Deltamethrin/Tralomethrin		0.00177	0.005
Lambda-cyhalothrin		0.00115	0.015
Permethrin cis		0.00352	0.015
Permethrin trans		0.00768	0.015
Benfluralin	Dinitroaniline (DN) (EMON-SM-05-006)	0.012	0.05
Ethalfluralin		0.015	0.05
Oryzalin		0.021	0.05
Oxyfluorfen		0.0101	0.05
Pendimethalin		0.012	0.05
Prodiamine		0.0124	0.05
Trifluralin		0.0144	0.05
Bromacil	Photosynthetic Inhibitor Herbicides and Norflorazon (TR) (EMON-SM-62.9)	0.031	0.05
Diuron		0.022	0.05
Hexazionone		0.04	0.05
Prometon		0.016	0.05
Simazine		0.013	0.05
Tebuthiuron		0.014	0.05
2,4-D	Synthetic Auxin Herbicides (PX) EMON-SM-05-012)	0.015	0.05
Dicamba		0.017	0.05
MCPA		0.022	0.05
Triclopyr		0.020	0.05

Table 7. Chemical analysis of pyrethroids in the northern California urban monitoring Study 299. The Department of Fish and Wildlife (DFW) will analyze sediment samples.

Pesticide	Method Detection Limit (ng g^{-1} dry wt)	Reporting Limit (ng g^{-1} dry wt)
Bifenthrin	0.063	0.25
Cyfluthrin	0.129	1.25
Cypermethrin	0.131	1.25
Deltamethrin/Tralomethrin	0.222	1.0
Esfenvalerate/Fenvalerate	0.131	0.5
Fenpropathrin	0.044	0.25
Lambda cyhalothrin	0.053	0.5
Permethrin, cis	0.484	1.25
Permethrin, trans	0.8	2.5

The procedures for pyrethroid extraction and analysis in sediment can be found at http://www.cdpr.ca.gov/docs/emon/pubs/anl_methds/wpcl_pr_008.pdf and http://www.cdpr.ca.gov/docs/emon/pubs/anl_methds/wpcl_ms_67.pdf, respectively

Table 8. Non-parametric procedures frequently used for comparing paired data, two samples and three or more samples.

Data	Non-Parametric Procedure
Paired data	*Wilcoxon signed-rank test* for uncensored data *Sign test* (modified for ties) for censored data with one RL *Score tests* for censored data with multiple RLs (the PPW test and the Akritas test)
Two samples	*Wilcoxon rank-sum (or Mann-Whitney) test* or *Kolmogorov-Smirnov test* for censored data with one RL *Score tests* for censored data with multiple RLs (the Gehan test and generalized Wilcoxon test)
Three or more samples in one-way layout	*Kruskal-Wallis test* (for unordered alternative) or *Jonckheere-Terpstra test* (for ordered alternative) for censored data with one RL *Generalized Wilcoxon score test* for censored data with multiple RLs *Multiple comparison* to detect which group is different
Three or more samples in two-way layout	*Friedman's test* (for unordered alternative) or *Page's test* (for ordered alternative) for censored data with one RL Multiple comparison to detect which group is different

Table 9.Total analytical chemistry costs for water monitoring.

Monitoring Project		Projected Cost
Ambient Monitoring		
Roseville	$92,340	
Sacramento (Arcade Creek)	$10,260	
San Francisco Bay Area	$10,800	
Ambient Monitoring Sub-total		$113,400
Mitigation Monitoring (Folsom)		$ 34,260
Bioassessment monitoring for contact 13-C0029		$ 4,980
Grand Total		$152,640

Figure 1. Long-term monitoring sites in Roseville, California. Arrows indicate water flow direction. PGC010, 021, and 022 are stormdrain outfalls; PGC040 is the downstream sampling site.

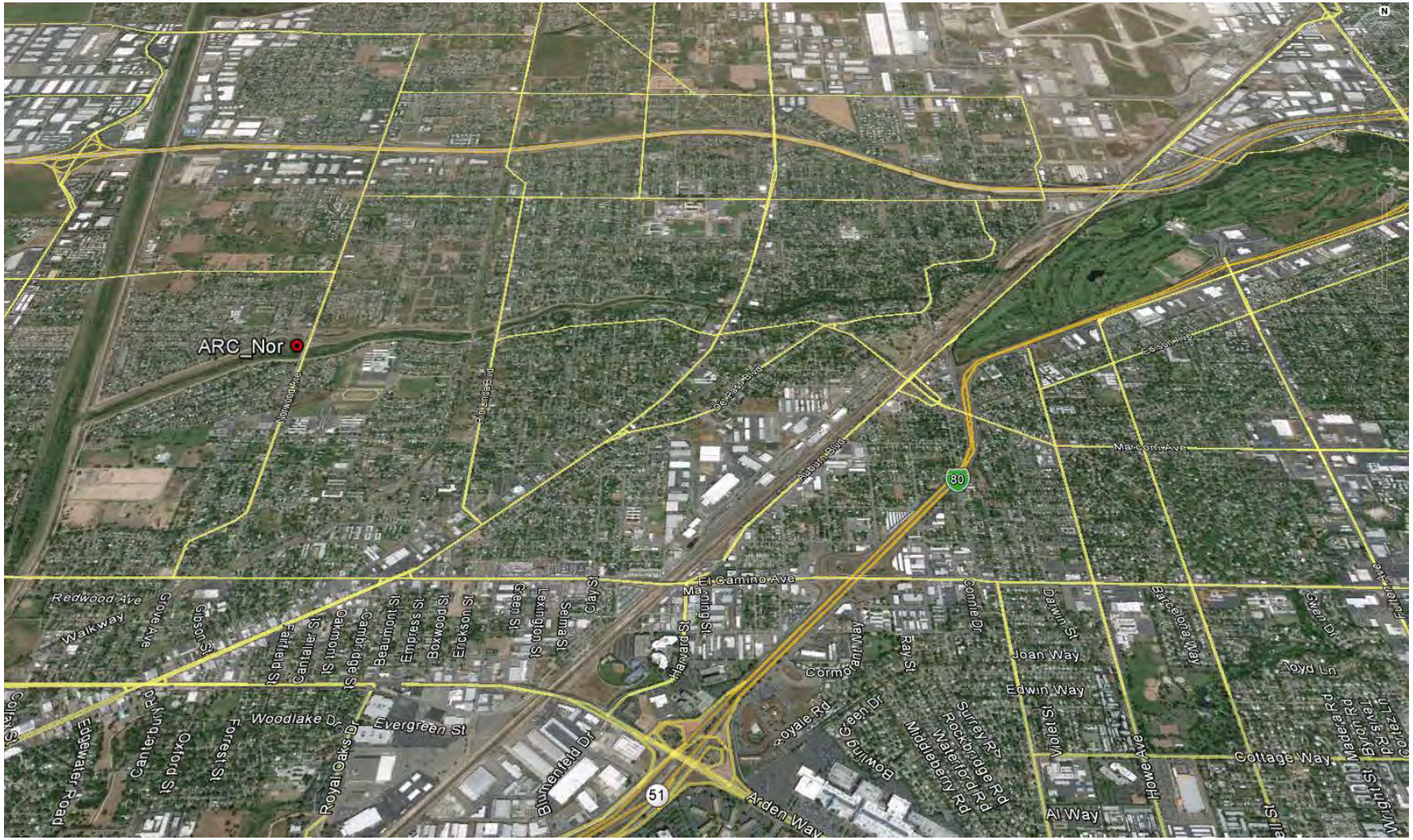


Figure 2. Monitoring site Arcade Creek at Norwood Avenue (ARC_Nor).

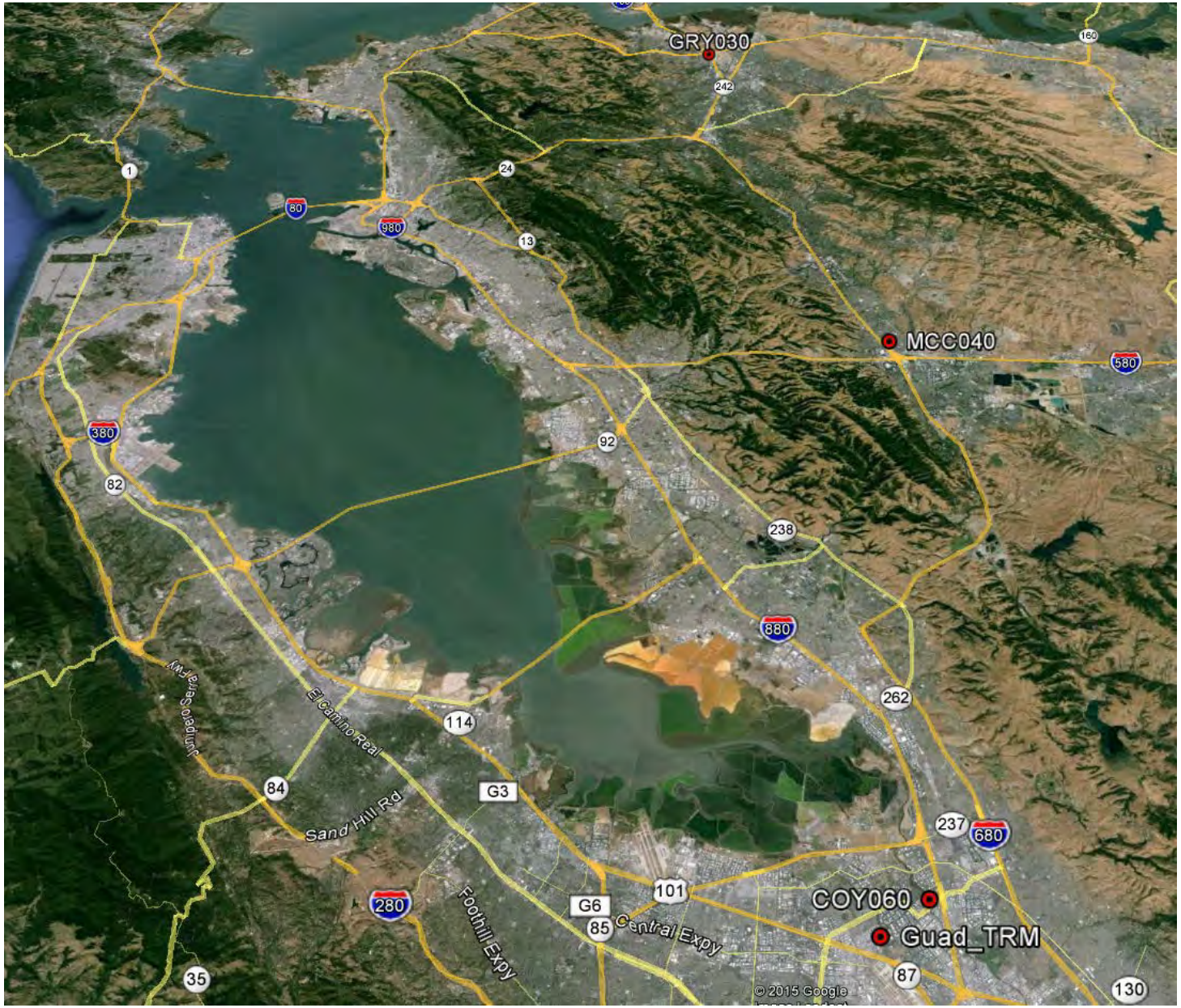


Figure 3. Monitoring sites in the San Francisco Bay Area (Pacheco, GRY030; Dublin, MCC040; San Jose, COY060 and Guad_TRM).

A. CWQTP on Natoma Station Drive

B. CWQTP on Marsh Hawk Drive

Figure 4. Two constructed water quality treatment ponds (CWQTP) in Folsom, California. The CWQTPs are outlined in yellow with arrows indicating water flow direction (inputs at TRP1, FOL2, and FOL3; outfalls at TRP2 and FOL5). Flow gaging equipment has been installed at the CWQTP on Marsh Hawk Drive (B, at FOL2, FOL3, and FOL5).

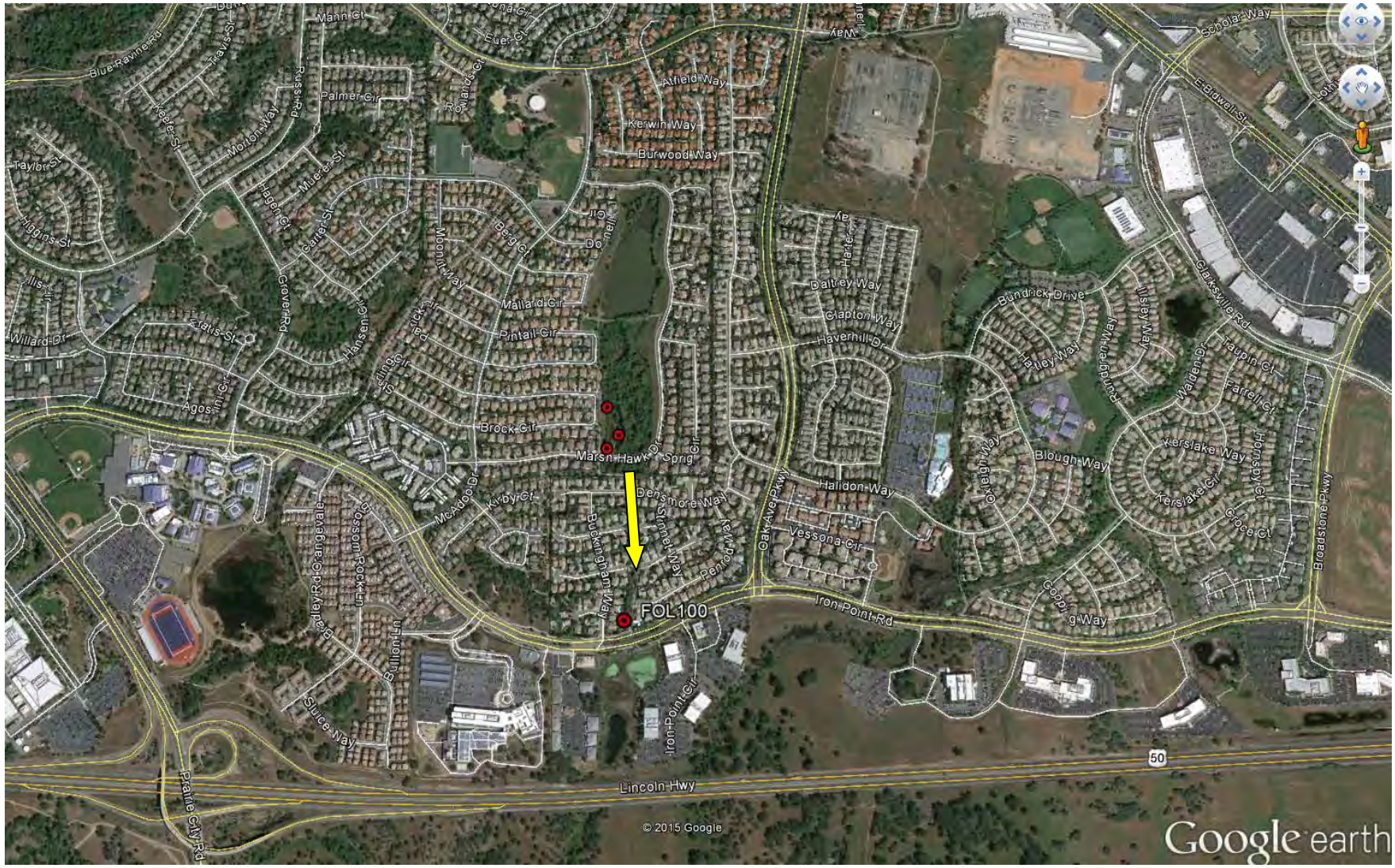


Figure 5. Folsom site F100 in relation to the mitigation monitoring sites at the Marsh Hawk Drive CWQTP. Arrow indicates direction of flow.

Appendix 1. Sampling site details for Study 299, FY 2015-16.

Site	Type/Description	No. Homes[§]	Area[§] (Acres)	GPS Coordinates (NAD83)	
				Latitude	Longitude
Ambient Monitoring: Roseville, California (sediment and water sampling)					
PGC010	Stormdrain outfall at Diamond Woods Circle, Roseville	250	56	38.80477	-121.32733
PGC021	Single storm drain outfall at Opal and Northpark Drive, Roseville	130	44	38.80267	-121.338551
PGC022	Dual stormdrain outfall at Opal and Northpark Drive, Roseville	375	112	38.802599	-121.338787
PGC040	Pleasant Grove Creek at Veteran's Park (receiving water)			38.79857	-121.34802
Ambient Monitoring: Sacramento, California (water sampling only)					
ARC_Nor	Arcade Creek at Norwood Avenue (receiving water)			38.623950	-121.457190
Ambient Monitoring: San Francisco Bay Area (water sampling only)					
GRY030	Grayson Creek at Center Avenue (receiving water)			37.983549	-122.068498
MCC040	Big Canyon/Martin Canyon Creek near Dublin Boulevard and I-680 (receiving water)			37.706412	-121.926687
Guad_TRM	Guadalupe River at Trimble Road (receiving water)			37.38062	-121.93802
COY060	Coyote Creek near Montague Expressway (receiving water)			37.3954	-121.91485
Mitigation Monitoring: Folsom, California					
CWQTP* at Marsh Hawk Drive (sediment and water sampling)					
FOL2	Stormdrain outfall; input at Brock Circle	252	65	38.6503	-121.14494
FOL3	Stormdrain outfall; input at Marsh Hawk Dr.	91	27	38.64938	-121.14494
FOL5	CWQTP outfall near Marsh Hawk Dr. (CWQTP area:~ 0.7 acres)			38.64969	-121.14459
CWQTP at Natoma Station Road (sediment sampling only)					
TRP1	Stormdrain outfall; input at Turn Pike and Natoma Station Dr.	385	110	38.64979	-121.18014
TRP2	CWQTP outfall near Turn Pike Dr. (CWQTP area: ~1.2 acres)			38.65062	-121.18098
Monitoring to support contract 13-C0029 (http://cdpr.ca.gov/docs/emon/surfwtr/contracts/ucdavis_13-C0029.pdf) (water samples only)					
FOL100	Receiving water at Iron Point Road			38.64559	-121.14442

[§]Approximate number of homes and area (Goggle Earth Pro, Mountain View, CA)
*Constructed water quality treatment pond as defined by the city of Folsom, CA

Appendix 2. Priority pesticides for Placer and Sacramento Counties. Listed, pesticides with priorities greater or equal to the priority score of 9, with a "TRUE" monitoring recommendation from the model. Priority model does not include homeowner pesticide use.

Pesticides with available analytical methods (CDFA)						
Pesticide	CDFA Screen*	Use (lb ai)	Use Score	Benchmark (µg/L)	Tox Score	Final Score
Bifenthrin	PY	21709	5	0.075	6	30
Permethrin	PY	14068	5	0.0106	6	30
Cyfluthrin	PY	6963	5	0.0125	6	30
Lambda-cyhalothrin	PY	570	3	0.0035	7	21
Fipronil	FP	6874	4	0.11	5	20
Cypermethrin	PY	1842	4	0.195	5	20
Deltamethrin	PY	499	3	0.055	6	18
Pendimethalin	DN	3915	4	5.2	4	16
Chlorfenapyr	CF	1688	4	2.915	4	16
Carbaryl	CY	1505	3	0.85	5	15
Malathion	OP	448	3	0.295	5	15
Esfenvalerate	PY	77	2	0.025	6	12
Imidacloprid	IMD	3469	4	34.5	3	12
Triclopyr	SA	1621	4	70	3	12
Oryzalin	DN	1570	4	15.4	3	12
Prodiamine	DN	1539	3	6.5	4	12
Diuron	PI	1027	3	2.4	4	12
Oxyfluorfen	DN	108	2	0.29	5	10
2,4-D	SA	758	3	13.1	3	9
Pesticides with no analytical methods (CDFA) - these pesticides will not be monitored until analytical methods become available						
Dithiopyr	--	3101	4	20	3	12
Sulfometuron-methyl	--	116	2	0.45	5	10
Indoxacarb	--	665	3	84	3	9
Propiconazole	--	522	3	21	3	9

*CY, carbaryl; CF, chlorfenapyr; DN, dinitroaniline herbicides+oxyfluorfen; FP, fipronil + degradates; IMD, imidacloprid; OP, organophosphates; PI, photosynthetic inhibitor herbicides; PY, pyrethroid; SA, synthetic auxin herbicides

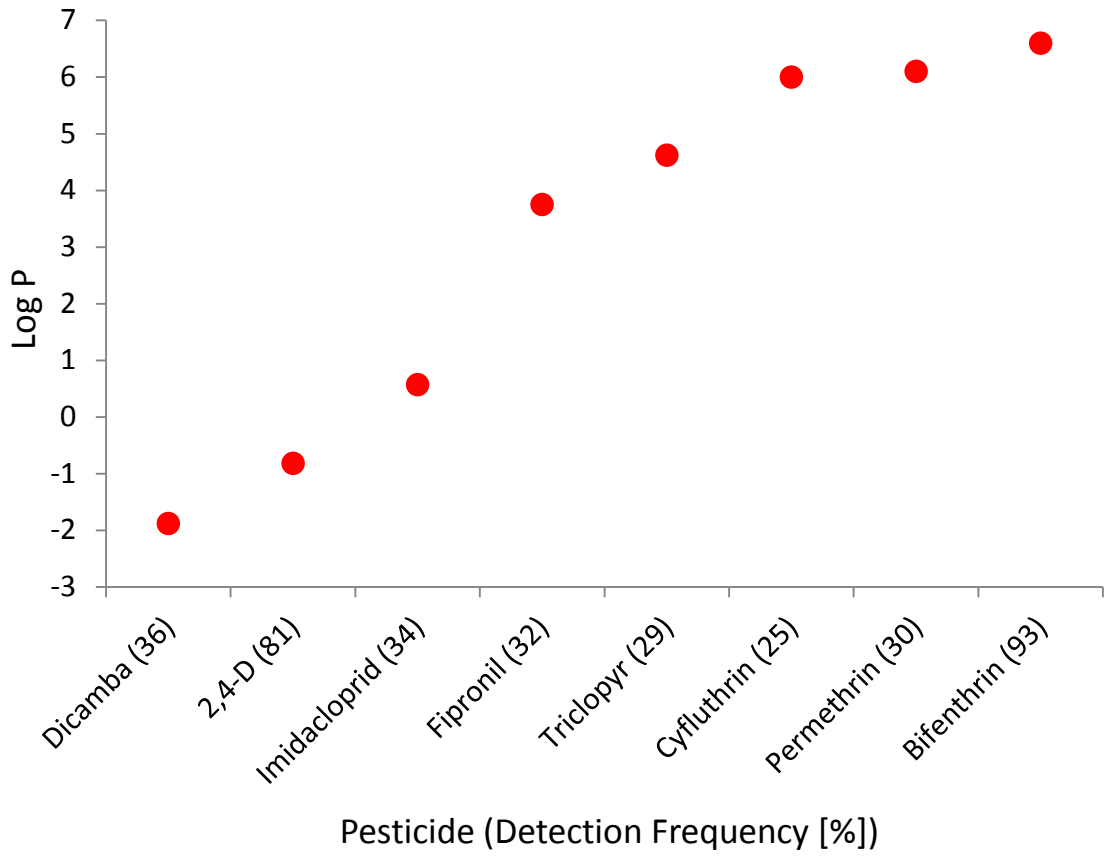
Appendix 3. Priority pesticides for Arcade Creek (ARC_Nor) in Sacramento County. Listed, pesticides with priorities greater or equal to the priority score of 9, with a "TRUE" monitoring recommendation from the model. Priority model does not include homeowner pesticide use.

Pesticides with available analytical methods (CDFA)						
Pesticide	CDFA Screen*	Use (lb ai)	Use Score	Benchmark (µg/L)	Tox Score	Final Score
Bifenthrin	PY	18,211	5	0.075	6	30
Permethrin	PY	13,080	5	0.0106	6	30
Cyfluthrin	PY	6,520	5	0.0125	6	30
Lambda-cyhalothrin	PY	514	3	0.0035	7	21
Fipronil	FP	6,178	4	0.11	5	20
Carbaryl	CY	1,496	4	0.85	5	20
Deltamethrin	PY	393	3	0.055	6	18
Chlorfenapyr	CF	1,542	4	2.915	4	16
Pendimethalin	DN	1,481	4	5.2	4	16
Cypermethrin	PY	942	3	0.195	5	15
Imidacloprid	IMD	2689	4	34.5	3	12
Oryzalin	DN	1195	4	15.4	3	12
Prodiamine	DN	880	3	6.5	4	12
Diuron	PI	461	3	2.4	4	12
Esfenvalerate	PY	72	2	0.025	6	12
Malathion	OP	315	2	0.295	5	10
Oxyfluorfen	DN	53	2	0.29	5	10
Triclopyr	SA	721	3	70	3	9
2,4-D	SA	444	3	13.1	3	9
Tebuthiuron	PI	322	3	50	3	9
Pesticides with no analytical methods (CDFA) - these pesticides will not be monitored until analytical methods become available						
Dithiopyr	--	2104	4	20	3	12
Sulfometuron-methyl	--	92	2	0.45	5	10
Indoxacarb	--	625	3	84	3	9
Propiconazole	--	323	3	21	3	9

*CY, carbaryl; CF, chlorfenapyr; DN, dinitroaniline herbicides+oxyfluorfen; FP, fipronil + degradates; IMD, imidacloprid; OP, organophosphates; PI, photosynthetic inhibitor herbicides; PY, pyrethroid; SA, synthetic auxin herbicides

Appendix 4. Priority pesticides for San Francisco Bay area sites.

Pesticide	CDFA Screen*	Use (lb ai)	Use Score	Benchmark (µg/L)	Tox Score	Final Score
Permethrin	PY	21722	5	0.0106	6	30
Bifenthrin	PY	10010	4	0.075	6	24
Cyfluthrin	PY	6189	4	0.0125	6	24
Deltamethrin	PY	4165	4	0.055	6	24
Lambda-cyhalothrin	PY	1528	3	0.0035	7	21
Fipronil	FP	6217	4	0.11	5	20
Cypermethrin	PY	2710	3	0.195	5	15

*FP, fipronil + degradates; PY, pyrethroid

Appendix 5. Detection frequencies and LogP values of pesticides monitored at the Marsh Hawk Constructed Water Quality Treatment Pond in Folsom, CA.