Environmental Science

Review of the Irrigated Lands Monitoring Program for the East San Joaquin River Watershed

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Acronyms and Abbreviations

AQL	aquatic life
C. dubia	*Ceriodaphnia dubia*
CEDEN	California Environmental Data Exchange Network
Coalition	East San Joaquin Water Quality Coalition
ILRP	Irrigated Lands Regulatory Program
MLJ-LLC	Michael L. Johnson LLC
MP	management practice
MPM	Management Plan Monitoring
NPS	nonpoint source
P. promelas	*Pimephales promelas*
PEP	pesticide evaluation protocol
POTW	publicly owned treatment works
RWQCB	Regional Water Quality Control Board
S. capricornutum	*Selenastrum capricornutum*
SWRCB	State Water Resources Control Board
TIE	toxicity identification evaluation
TMDL	total maximum daily load
TRE	toxicity reduction evaluation
WDR	waste discharge requirement
WET	whole effluent toxicity
WQTL	water quality trigger limit
WY	water year

Limitations

This report summarizes work performed to date and presents the findings resulting from that work. The findings presented herein are made to a reasonable degree of scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available through any additional work or review of additional work performed by others.

Executive Summary

Since 2004, water quality data have been collected in the State's receiving waters to characterize water quality downstream of irrigated lands. Discharges from irrigated lands are considered nonpoint sources, and monitoring to evaluate the water quality impacts of nonpoint sources is more logistically and technically challenging than monitoring traditional point source discharges. As a result, monitoring programs to characterize water quality downstream of agricultural operations have generated significant discussion. The State Water Resources Control Board (SWRCB) issued an order after review of the Central Coast agricultural Waste Discharge Requirements (WDRs), convened an Agricultural Expert Panel that addressed surface water monitoring (among other issues), evaluated data from irrigated lands monitoring programs, and, most recently, issued a second Draft Order WQ 2018-___ to address issues related to WDR General Order No. R5-2012-0116 (Eastern San Joaquin Agricultural General WDRs).

Exponent was retained to review the SWRCB's second Draft Order, the surface water monitoring plan developed by the East San Joaquin Water Quality Coalition (Coalition), and surface water data gathered by the Coalition since 2004. Exponent's work focused on evaluating the monitoring program's efficacy with regards to temporal and spatial sample density, the ability of the program to capture exceedances of water quality trigger limits (WQTL), and the ability to provide data to evaluate the effectiveness of management actions and implementation measures. In conducting this work, Exponent reviewed data characterizing land use, crop types, pesticide use, water quality, and toxicity within the Coalition area, and Exponent performed statistical and trend analysis to evaluate data generated by the program over time.

As detailed in this report, Exponent has reached the following conclusions:

- Core and Represented monitoring sites within the six zones delineated by the Coalition provide sufficient spatial coverage.

- The monitoring program has generated data that identify changes in water quality over time. These data confirm that management practices on irrigated lands have improved water quality.
- Naturally occurring constituents and constituents with multiple sources show higher variability than constituents that originate primarily from agricultural sources. Data gathered by the monitoring program indicate that non-agricultural sources are likely important causes of water quality exceedances.
- The Coalition’s monitoring program uses a structured framework to incorporate data on chemical use, relative risk, exposure, and chemical behavior in the environment in order to tailor monitoring and implementation measures and to maximize the likelihood that water quality problems will be identified.

Note that this Executive Summary does not contain all of Exponent’s technical evaluations, analyses, conclusions, and recommendations. Hence, the main body of this report is at all times the controlling document.

1 Qualifications

My name is Susan Paulsen, and I am a Registered Professional Civil Engineer in the State of California (License # 66554). My educational background includes a Bachelor of Science in Civil Engineering with Honors from Stanford University (1991), a Master of Science in Civil Engineering from the California Institute of Technology (“Caltech”) (1993), and a Doctor of Philosophy (Ph.D.) in Environmental Engineering Science, also from Caltech (1997). My education included coursework at both undergraduate and graduate levels on fluid mechanics, aquatic chemistry, surface and groundwater flows, and hydrology, and I served as a teaching assistant for courses in fluid mechanics and hydrologic transport processes. A copy of my *curriculum vitae* is included as Appendix A.

I am currently a Principal and Director of the Environmental and Earth Sciences practice of Exponent, Inc. (“Exponent”). Before that, I was the President of Flow Science Incorporated, in Pasadena, California, where I worked for 20 years, first as a consultant (1994–1997), and then as an employee in various positions, including President (1997–2014). I have 25 years of experience with projects involving hydrology, hydrogeology, hydrodynamics, aquatic chemistry, and the environmental fate of a range of constituents. I have knowledge of California water supply and water quality issues. My expertise includes designing and implementing field and modeling studies to evaluate groundwater and surface water flows and contaminant fate and transport. I have designed studies using one-dimensional hydrodynamic models, three-dimensional computational fluid dynamics models, longitudinal dispersion models, and Monte Carlo stochastic models, and I have directed modeling studies and utilized the results of numerical modeling to evaluate surface and ground water flows.

I have designed and implemented field studies in reservoir, river, estuarine, and ocean environments using dye and elemental tracers to evaluate the impact of pollutant releases and treated wastewater, thermal, and agricultural discharges on receiving waters and drinking water intakes. I have also designed and managed modeling studies to evaluate transport and mixing, including the siting and design of diffusers, the water quality impacts of storm water runoff, irrigation, wastewater and industrial process water treatment facilities, desalination brines and cooling water discharges, and groundwater flows.

In the preparation of this report, I relied on my colleague Melanie Edwards to assist with data analytics. Ms. Edwards is an accredited statistician and has testified on the use of statistical methods. She regularly performs and critiques data analytics of lab chemistry concentrations, toxicity tests, field screening results, and background or reference comparisons. She is called upon frequently to provide understandable descriptions of statistical methods. Her areas of application have include environmental chemical forensics and pesticide registration. With over 20 years of experience, Ms. Edwards has provided statistical support on projects involving metals, PCBs, PAHs, and dioxins/furans in soil, sediment, dust, groundwater, and surface water.

Ms. Edwards routinely provides insight on data presentation and interpretation of statistical analyses for experts from a variety of backgrounds, including environmental science, ecology, toxicology, and engineering. She is also familiar with public data sources such as NHANES and SEER data repositories as well as chemistry datasets representing background concentrations in soil and water. She has maintained all aspects of databases used for data validation, compilation, and storage, including transfer of data from multiple formats. Ms. Edwards has provided statistical support on a wide range of projects including chemical fingerprint analyses, model fitting and predictions, comparisons with background and reference populations, probabilistic model development for quantification of uncertainties, and evaluation of toxicity test results. Methods used include regression, analysis of variance, non-linear models, factor analysis, principal component analysis, non-parametric methods, and sampling design and evaluation. A copy of Ms. Edwards’ CV is included in Appendix A.

2 Introduction

In 2004, the State Water Resources Control Board (SWRCB) adopted the Policy for Implementation and Enforcement of the Nonpoint Source (NPS) Pollution Control Program (NPS Policy),[1] which specifies five key elements required of any NPS implementation program. These five elements are intended to produce an implementation program that will attain water quality objectives and protect beneficial uses. Monitoring is a key element of a successful NPS implementation program, as monitoring is necessary to evaluate whether an implementation program achieves and maintains water quality objectives and beneficial uses; to evaluate the effectiveness of management practices (MPs); to provide feedback for use in adaptive management; and to provide sufficient data for the Regional Water Quality Control Board (RWQCB), dischargers, and the public to determine whether the implementation program is achieving its purposes. The NPS Policy provides that a coalition of dischargers can be organized around watersheds, discharge characteristics, and discharge community type, among other commonalities, to implement an NPS implementation program to identify and address threats to water quality. The NPS Policy also provides an option for a "Third Party" to assist with the development and implementation of a program for a coalition of dischargers.

The Central Valley RWQCB initiated its Irrigated Lands Program in 2003 "to prevent agricultural runoff from impairing surface waters."[2] In 2006, the Central Valley RWQCB adopted a conditional waiver of waste discharge requirements (WDRs), which was directed at "coalition groups," and in 2012, the RWQCB adopted agricultural WDRs intended to protect both surface water and groundwater. Six orders adopted by the Central Valley RWQCB have been petitioned to the SWRCB, and the SWRCB requested the administrative record and responses to the Eastern San Joaquin River Watershed petitioners' contentions.

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[1] State Water Resources Control Board. 2004. Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program. May 20.

[2] California Nonpoint Source Program Implementation Plan, 2014–-2020; August 2015; see https://www.waterboards.ca.gov/water_issues/programs/nps/docs/plans_policies/sip_2014to2020.pdf p. 204.

Agricultural WDRs issued by the Central Coast RWQCB in 2012 were reviewed by the SWRCB in 2013, and the SWRCB amended several requirements as discussed in Order WQ 2013-0101, issued in September 2013. Among the amended requirements were:

> those with regard to approval of alternative third party water quality improvement projects and monitoring and reporting programs, authority of the executive officer to change tier designations, compliance with water quality standards and effective control of certain pollutants, maintenance of containment structures, recording of practice effectiveness and compliance in the farm plan, cooperative groundwater monitoring, photo monitoring, monitoring of individual surface water discharges, reporting of total nitrogen application, reporting of elements of the irrigation and nutrient management plan, and compliance with nitrogen balance ratio milestones.[3]

In 2013-2014, the SWRCB convened an Agricultural Expert Panel to address questions related to the water quality impacts of agriculture. Although the panel focused primarily on issues related to nitrates in groundwater, the Expert Panel Report[4] included recommendations for surface water monitoring programs. The Expert Panel Report also noted that monitoring and regulatory approaches for NPS differ in fundamental ways from those for point sources, particularly in that there is "a relatively long history of development of monitoring / regulatory approaches for point-source pollution, but the approaches are not necessarily transferable to non-point-source monitoring and regulation."[5]

Exponent was retained by Somach Simmons and Dunn to review the second staff-proposed order SWRCB/OCC Files A-2239(a)-(c) regarding WDRs General Order No. R5-2012-0116. Specifically, Exponent was asked to review the East San Joaquin Water Quality Coalition's (Coalition) existing surface water monitoring program and use of data gathered by the Coalition since 2004 to evaluate the monitoring program's efficacy regarding temporal and spatial sampling density, the ability to capture exceedances of water quality trigger limits (WQTLs),

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[3] SWRCB. 2013. Order WQ 2013-0101.

[4] Irrigation Training & Research Center, California Polytechnic State University (Cal Poly), Conclusions of the Agricultural Expert Panel: Recommendations to the State Water Resources Control Board pertaining to the Irrigated Lands Regulatory Program. Sept 9, 2014.

[5] Ibid., p. 8.

and the ability to provide data to evaluate the effectiveness of the management actions and implementation measures. In conducting this work, Exponent reviewed data from the California Environmental Data Exchange Network (CEDEN) website and information supplied by Michael L. Johnson, LLC (MLJ-LLC) staff (consultant to the Third Party, which is the Coalition).

Exponent's analysis focused on using data from the monitoring program (2004–present) to address several key issues outlined in the SWRCB Draft Order:

- Is the Coalition's monitoring program of sufficient spatial and temporal density to identify WQTL exceedances and problem areas? (p. 59)
- Are the Core and Represented sites comparable to regional or watershed-based sampling? (p. 59)
- Is an exceedance at a Core site indicative of an exceedance at a Represented site? (p. 59)
- Are Core and Represented sites representative of one another, even if they exhibit differences in exceedance rates for different constituents? (p. 59)
- Can surface water monitoring be used to evaluate management practice effectiveness? (p. 57)
- Does the Coalition's monitoring program include sufficient feedback mechanisms to indicate whether the program is achieving its stated purposes? (p. 60)

3 Surface Water Monitoring

3.1 Surface Water Monitoring Programs

Because it is not possible to conduct surface water monitoring at all places and all times, monitoring programs are designed to "sample" receiving waters. A well-constructed monitoring program will allow for the assessment of a system using observations at a few select locations and points in time that are representative of the system. A monitoring plan is developed to describe how monitoring will be conducted and how data will be collected, handled, and interpreted. An effective monitoring program must determine appropriate sample sizes, frequencies, locations, and analyses. Specific guidance on the limitations faced in determining an appropriate number of samples to represent a system is available,[6] though the unique characteristics of each watershed must be accounted for. As explained by the Agricultural Expert Panel in the Expert Panel Report:

> [S]ufficient samples should be taken in the watershed streams to detect if problems do indeed exist. The sampling should be of sufficient density (spatially and temporally) to identify general locations of possible pollution. This is recommended rather than sampling at each discharge point … Individual point discharge measurements/monitoring would be used only if individual points are identified as being serious contributors to water quality problems, based on samples taken upstream in the watershed.[7]

Under ideal conditions, monitoring and sampling locations should be either targeted (if a specific area requires monitoring) or random (to best represent the system as a whole). The

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[6] See, for example, Law et al. 2008. Monitoring to Demonstrate Environmental Results: Guidance to Develop Local Stormwater Monitoring Studies Using Six Example Study Designs. Center for Watershed Protection. https://www.epa.gov/sites/production/files/2015-11/documents/monitoring_guidance_full_report.pdfhttps://www.epa.gov/sites/production/files/2015-11/documents/monitoring_guidance_full_report.pdf.

[7] Irrigation Training & Research Center, California Polytechnic State University (Cal Poly), Conclusions of the Agricultural Expert Panel: Recommendations to the State Water Resources Control Board pertaining to the Irrigated Lands Regulatory Program. Sept 9, 2014. p. 41

random approach to selecting sampling locations is more common;[8] however, a variety of logistical considerations must be addressed when creating and modifying an environmental monitoring plan. At the field or small watershed scale, limitations often include climate, physical access, personnel safety, equipment availability, and budget. In some systems, access to sampling locations is limited by legal and/or physical constraints. In such cases, professional judgment and information on accessibility would be used to determine site locations.

Additional considerations include sampling frequency (the number and frequency of samples that must be taken and analyzed to appropriately characterize a system), field sampling and measurement instruments, analytical requirements, and transportation requirements for site access (foot, automobile, boat, helicopter, etc.). For flowing waters, most monitoring plans require monitoring events at various flow stages. For example, baseflow monitoring generally occurs in perennial streams at regular intervals to capture representative data on water quality and flow, while in ephemeral streams, sampling at regular intervals can be used to define conditions during wet periods and to determine when water is present. Additionally, storm water monitoring is conducted immediately after a significant rain event to measure runoff, turbidity or sediment load, and water quality parameters during storm conditions.[9] Storm flow monitoring is typically more difficult and expensive than baseflow monitoring, but the data are important for characterizing episodic loads to receiving waters. Mobilization for wet weather sampling is also challenging, as weather cannot always be reliably predicted; runoff may occur when field personnel are not ready or available, and access is frequently more challenging during storm conditions. Sampling during storm conditions can pose additional health and safety concerns for field personnel (e.g., washed out roads, high flow, loose debris, poor weather conditions, nighttime sampling). The flow chart shown in Figure 3-1[10] depicts some of the decisions that

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[8] Barbour, M.T. et al. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, 2nd Edition. U.S. Environmental Protection Agency US EPA, Office of Water. EPA 841-B-99-002.

[9] Ibid.

[10] U.S. EPA. 2003. National Management Measures for the Control of Nonpoint Pollution from Agriculture. U.S. Environmental Protection Agency. EPA 841-B-03-004. July 2003.

must be considered in formulating a monitoring plan for evaluating NPS pollution from agriculture. Figure 3-1 also illustrates the importance of feedback and adaptive management.

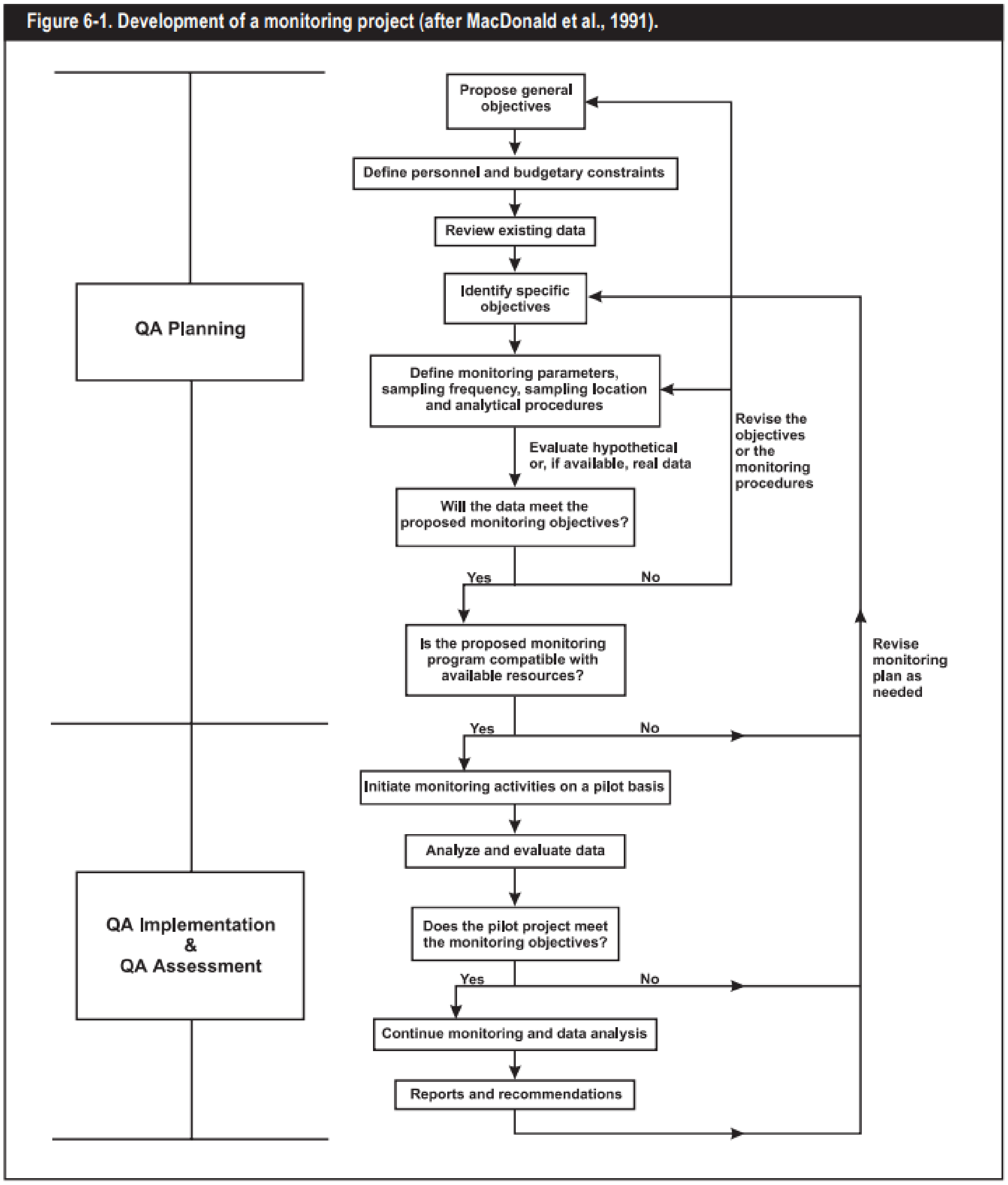

Figure 3-1. Considerations in the development, implementation, and revision of a monitoring plan (U.S. EPA 2003)

Thus, a comprehensive and representative monitoring plan requires a careful and thoughtful balance between project requirements and logistical considerations. In my opinion, an irrigated lands monitoring program to evaluate surface water quality impacts should be designed to:

- Strategically identify pollutants and conditions to be monitored to identify water quality concerns arising from irrigated agriculture.
- Determine the concentrations of key pollutants in surface waters.
- Identify exceedances of narrative and numeric water quality objectives to determine whether implementation of additional MPs is necessary to improve and/or protect water quality.
- Determine the effectiveness of MPs and strategies to reduce water quality impacts from irrigated agriculture.
- Incorporate sufficient flexibility to respond to environmental variability using an adaptive management framework, and use monitoring results to trigger timely implementation of response actions and MPs.

3.1.1 Variability

The complexity and variability of a natural system such as a watershed must be addressed when developing an environmental monitoring and sampling program, particularly when data are to be collected over long periods. Variability occurs both naturally[11]—for example, as a result of changing weather patterns, antecedent conditions, seasonality, natural sources, daily fluctuations in ecological processes and water quality parameters—and due to anthropogenic factors, such as landscape and land-use changes, sampling bias among field equipment and personnel, and

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[11] See, for example, Stein, E.D. and V.K. Yoon 2007. Assessment of water quality concentrations and loads from natural landscapes. Southern California Coastal Water Research Project (SCCWRP) Technical Report No. 500. February. Available at ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/500_natural_loading.pdf.

Tiefenthaler, L. 2010. Assessment of water quality from natural landscapes. Symposium presentation. January 20. Available at http://ftp.sccwrp.org/pub/download/PRESENTATIONS/Symposium2010/NaturalWaterQuality_1_Tiefenthaler_WatershedReference.pdf.

Schiff, K. et al. 2010. Assessing water quality conditions in southern California's areas of special biological significance. SCCWRP 2010 Annual Report at pp. 251-260. Available at ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/AnnualReports/2010AnnualReport/ar10_251_260.pdf.

laboratory and analytical variability. Understanding and characterizing variability is critical to interpreting environmental data and refining the monitoring program.[12]

The Expert Panel Report[13] identified several other sources of variability which can influence water quality data and the collection of those data for irrigated lands: "the timing of individual sample collection might not coincide with pesticide applications, or with events of high sediment runoff. It is difficult to identify, in advance, exactly when (time of day and day) there might be surface runoff. This is because irrigation schedules constantly change as [agricultural] field crews shift operations."

Sampling programs should be designed to capture a representative range of conditions and, where possible, the impacts of specific management actions (e.g., pesticide applications, erosion control measures) and events (e.g., storm events, low and high flow events). To the extent feasible, monitoring programs should employ aggregate measures that characterize effects. For example, whole effluent toxicity (WET) testing can be performed to measure effects directly and as a trigger for additional analyses designed to identify the source of negative effects (e.g., toxicity identification evaluations [TIEs] or toxicity reduction evaluations [TREs]). Toxicity testing is frequently regarded as a "catch all," as it is used to assess water quality impacts and to overcome one of the principal limitations of the chemical-specific approach, in that all possible contaminants are not monitored or may not be known.[14]

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[12] Barbour, M.T. et al. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, 2nd Edition. U.S. Environmental Protection Agency, Office of Water. EPA 841-B-99-002.

[13] Irrigation Training & Research Center, California Polytechnic State University (Cal Poly), Conclusions of the Agricultural Expert Panel: Recommendations to the State Water Resources Control Board pertaining to the Irrigated Lands Regulatory Program. Sept 9, 2014. p. 40.

[14] U.S. EPA 1991. Technical Support Document for Water Quality-based Toxics Control. US Environmental Protection Agency, Office of Water. EPA0/505/2-90-001. Washington, DC.

Grothe, DR, Dickson, KL, and Reed-Judkins, DK. 1996. Whole Effluent Toxicity Testing: An Evaluation of Methods and Prediction of Receiving System Impacts. SETAC Press, Pensacola, FL 346p.

Norberg-King, TJ, Ausley, LW, Burton, DT, Goodfellow, WL, Miller JL, and Waller, WT. 2005. Toxicity Reduction and Toxicity Identification Evaluations for Effluents, Ambient Waters, and Other Aqueous Media. SETAC Press, Pensacola, FL. 455p.

While monitoring results for traditional point sources (e.g., publicly owned treatment works [POTWs], industrial process water discharges) may be characterized by standard statistical distributions (usually normal or log-normal), NPS monitoring results may not follow these distributions because of the variety of factors influencing the monitoring measurement. The statistical characteristics of point source monitoring data can be used to calculate the expected range of values (confidence or control limits, for example) that then identify when processes may have drifted from standard operations or typical conditions.

Because of the variability inherent in environmental monitoring and specific to NPSs such as irrigated lands, it is not reasonable to expect data to be reproducible in the traditional sense. For example, samples collected at a given location on a given date (e.g., samples collected at a Core monitoring location on October 1) will not be the same from year to year because of changes in crop patterns, pesticide applications, weather conditions, and other factors. Similarly, it is not possible to "track" the source of a water quality exceedance upstream, as analytical results for a water sample will be available days to weeks after sample collection, and environmental conditions will have changed before field personnel would be able to re-deploy to collect additional samples from upstream locations.

If exceedances are used to trigger implementation of management actions, as they should in a responsive and effective monitoring program, those management actions will affect subsequent monitoring results. Management actions should have an effect that will be observable over time, even given variability. Comparison of exceedance rates at locations sampled under multiple management actions can be compared, and reductions in exceedance rates are considered indicative that outreach efforts are effective in reducing water quality issues.

Logistical considerations (e.g., access, sampling effort, feasibility) typically preclude the implementation of a Lagrangian approach whereby a "parcel" of water is sampled repeatedly as

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USEPA. 2000. Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testimony (40 CFR Part 136). U.S. Environmental Protection Agency. EPA 821-B-00-004. July 2000. P 1-1. Document available at: https://www.epa.gov/sites/production/files/2016-02/documents/method-guidance-recommendations-wet-testing_2000.pdf.

it travels downstream through a watershed. Lagrangian approaches are typically used to answer very specific questions such as how the geochemical composition of water changes within a system over time[15] or to track the fate and impacts of pollutants from discrete point sources.[16] Discharges from irrigated lands throughout irrigation season are spatially and temporally diffuse due to unpredictable timing of chemical application, precipitation events, irrigation schedules, and other confounding factors. A Lagrangian approach is logistically challenging, and even if implemented it would be difficult to capture exceedance events and identify responsible parties due to the nature of irrigated lands discharges. For these reasons, it is neither feasible nor reasonable to implement a monitoring approach for NPS discharges, such as discharges from irrigated lands, that tracks exceedances upstream.

3.1.2 Field Work Considerations and Analytical Requirements

Physical access to monitoring locations can be both a legal issue and a health and safety issue. When access requires crossing over privately owned land, permission must be arranged with the owner ahead of time. The health and safety of all field personnel must be considered in all aspects of field monitoring work, including transport and access to the monitoring site. Health and safety considerations include, but are not limited to, safe transportation conditions, weather conditions, exposure to the elements, potentially dangerous wildlife, direct lines of communication from remote areas, first aid training and supplies, and appropriate personal protective equipment. Accessing a monitoring location from a busy road, highway, or overpass involves additional legal and health and safety concerns.

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[15] Paulsen, S.C. A study of the mixing of natural flows using ICP-MS and the elemental composition of waters. Dissertation (Ph.D.), California Institute of Technology (Caltech).

[16] T. Kraus et al. 2017. A river-scale Lagrangian experiment examining controls on phytoplankton dynamics in the presence and absence of treated wastewater effluent high in ammonium. Limnology and Oceanography 62:1234-1253, May 2017.

Barber, L.B., Keefe, S.H., Kolpin, D.W., Schnoebelen, D.J., Flynn, J.L., Brown, G.K., Furlong, E.T., Glassmeyer, S.T., Gray, J.L., Meyer, M.T., Sandstrom, M.W., Taylor, H.E., and Zaugg, S.D.,. 2011. Lagrangian sampling of wastewater treatment plant effluent in Boulder Creek, Colorado, and Fourmile Creek, Iowa, during the summer of 2003 and spring of 2005—Hydrological and chemical data: U.S. Geological Survey Open-File Report 2011–1054, 84 pp.

Field equipment employed in water monitoring programs can range in cost from a few dollars to thousands of dollars. In addition to costs associated with renting and purchasing equipment, time and materials are needed to adequately clean, maintain, and calibrate field equipment. In some situations, backup equipment may be needed (e.g., for remote locations or for capturing storm events) in case a primary tool or sensor breaks down. Additional equipment such as water proof cases, walkie talkies, cell phones, survey equipment, and GPS may be necessary or useful to have on hand, and the logistics of obtaining, maintaining, and using needed equipment must also be considered in developing a monitoring program.

The Expert Panel Report[17] mentioned many of these considerations, citing (for example) labor schedules that limit sample collection to daylight hours only, lab operations schedules and sample holding times, and other factors that make sampling of some events (e.g., storm events) particularly challenging. Sample holding times range anywhere from 24 hours (*E. coli* analyses) to a year, depending on the analytical parameter. The pesticide chlorpyrifos, for example (an organophosphate), must be extracted within 7 days of collection and analyzed within 40 days of collection. Analytical laboratories may only operate Monday through Friday, and can have substantial queues, particularly during intensive sampling times such as first-flush storm events, so planning is essential when sampling for analytes with short holding times.

3.2 Coalition Irrigated Lands Monitoring Program

3.2.1 Program History

The Coalition's surface water monitoring program has undergone three substantial revisions since it began in 2004. The three major iterations in monitoring approach are described briefly below.

2004–2008: Monitoring was conducted at established locations during the irrigation season and during two storm events per year. Where water or sediment toxicity was identified, resampling

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[17] Irrigation Training & Research Center, California Polytechnic State University (Cal Poly), Conclusions of the Agricultural Expert Panel: Recommendations to the State Water Resources Control Board pertaining to the Irrigated Lands Regulatory Program. Sept 9, 2014. p. 41.

was conducted within 72 hours of notification of toxicity. In addition to normal sampling, sampling locations with chemical or toxicological exceedances were resampled during the same month of the following year for the specific constituent that caused the exceedance. Monitoring results were shared with Coalition members and other interested parties through the Coalition's annual report and through mailings. Growers were encouraged to attend large meetings seasonally, where information on best management practices and specific water quality concerns was presented. During 2008, sampling was conducted upstream of locations with exceedances from the prior year (2007); upstream monitoring was done for one year.

2008-September 2013: In 2008, the monitoring program was updated to divide the Coalition monitoring area into six zones based on hydrology, crop types, land use, soil types and rainfall; each zone contained one Core site and multiple Assessment sites (Figure 3-2). Table 3-1 presents the acreage of each zone and the acreage that drains to the Core monitoring locations. Core sites within each zone were monitored monthly for two consecutive years for physical parameters and nutrients. All of the core sites had also been monitored prior to 2008. During the third year, monthly Assessment Monitoring was conducted at Core Monitoring sites; Assessment Monitoring included the analysis of a large suite of constituents including toxicity, pesticide and metals in addition to the Core Monitoring constituents. At least one Assessment site was monitored in addition to the Core site for that zone. The selected Assessment site was monitored for at least 2 consecutive years before monitoring moved to a different Assessment site in the same zone. All subwatershed sampling locations were chosen to specifically assess agricultural drainage. In addition, two types of targeted sampling were conducted; one type captured two storm events[18] annually, and the second type continued to monitor at a site for a constituent that had exceeded a WQTL previously. Along with additional sampling, farms in individual subwatersheds where exceedances occurred received focused outreach and education programs about MPs that could improve water quality. MLJ-LLC has indicated that the focused outreach phase was prioritized to consider the type of exceedance and frequency and magnitude

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[18] A storm event is defined as monitoring within three days of a rainfall event that exceeded 0.25 inches within a 24-hour period. If regular monitoring sampling is scheduled within a week of a forecast storm then sampling can be rescheduled to the storm event, otherwise storm sampling may result in sampling twice in a single month. Source: MLJ-LLC. 2017. Annual Report October 2015-September 2016. Irrigated Lands Regulatory Program Central Valley Regional Water Quality Control Board. May 17, 2017. p. 32.

of exceedances, such that some individual dischargers in lower priority situations did not receive focused outreach until the end of this period. Most outreach occurred outside of the irrigation season (when growers are less busy) such that effects of the outreach were generally not expected until the following growing season. The focused outreach program involved multiple hours spent with farmers on their properties, and it was infeasible to reach every farmer every year. Focused outreach was targeted based on MP review and pesticide usage, while general educational outreach was provided to all growers every year.

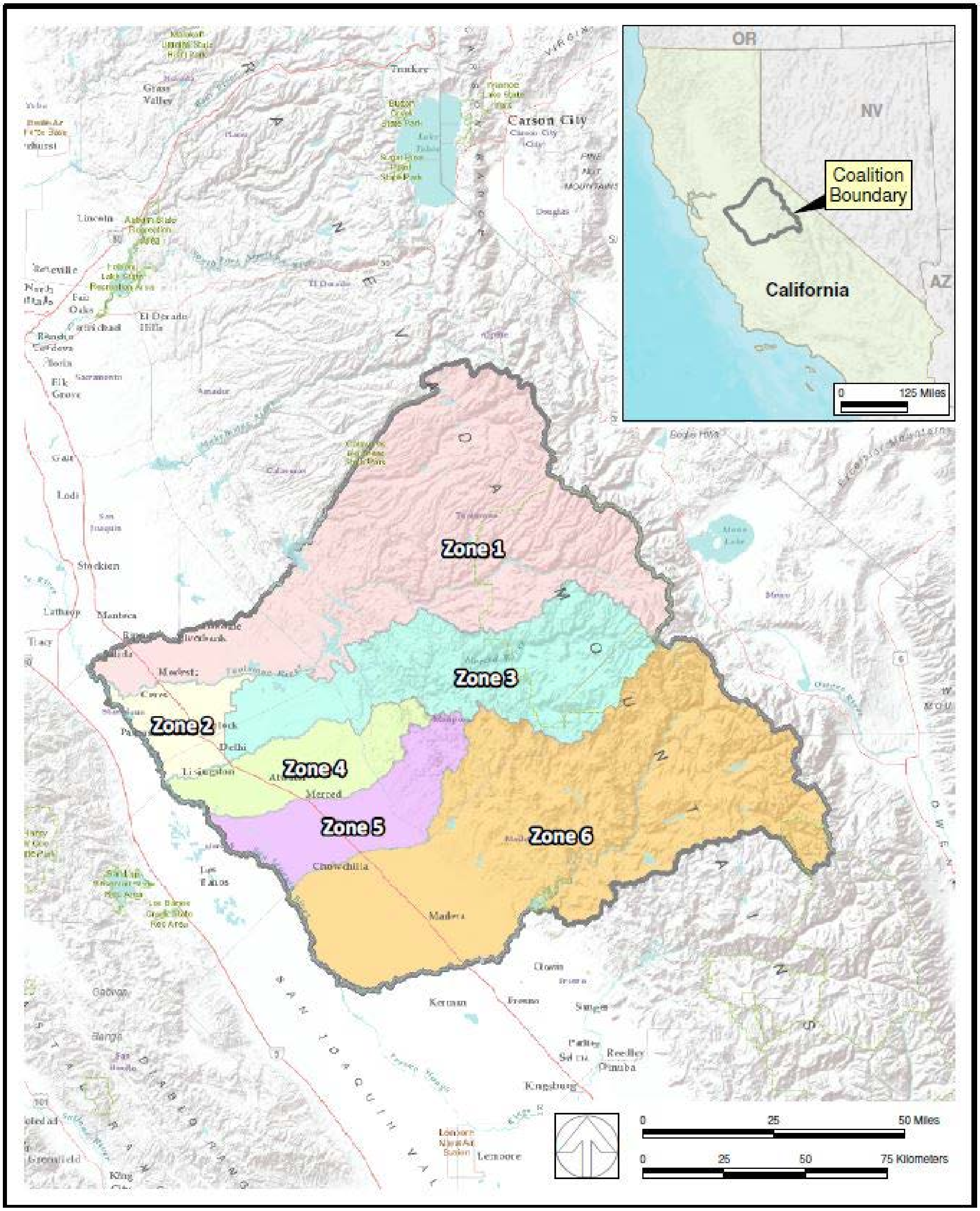

Figure 3-2. Coalition boundary and zones

Table 3-1. Irrigated acreage by monitoring zone[19]

Zone	Irrigated Acreage in Zone	Irrigated Acres Upstream of Core Monitoring Sites[a]
1 Dry Creek @ Wellsford Rd	120,292	88,057
2 Prairie Flower Drain @ Crows Landing Road	143,060	3,126
3 Highline Canal @ Hwy 99	90,283	38,975
4 Merced River @ Santa Fe	118,682	130,139[b]
5 Duck Slough @ Gurr Rd	160,604	51,440
6 Cottonwood Creek @ Rd 20	349,321	98,725
Sum	982,242	410,462

[a] Includes all irrigated land use types, not strictly agricultural (e.g., pasture land, urban landscapes, urban residential, native vegetation, etc.).

[b] The irrigated acreage upstream of this monitoring site is greater than the irrigated acreage of Zone 4 due to significant subwatershed overlap into Zone 3 (see Figure 4-1).

October 2013–Present: In December 2012, WDR Order R5-2012-0116-R1 was adopted (revised October 3, 2012) for Coalition growers within the Eastern San Joaquin River watershed. Under this order, the Coalition's monitoring program transitioned to the current monitoring program and outreach efforts were refined, as described in detail in the following section.

3.2.2 Current Coalition Monitoring Program

The existing monitoring program was designed "to measure improvements in water quality and the effectiveness of focused management practice outreach and tracking."[20] Each of the six zones were assigned two alternating Core sites and one or more Represented sites (Figure 3-3). Most of these sampling locations have been sampled in prior monitoring programs. Core sites were chosen to represent the zone as a whole, while the Represented sites were selected to represent a subwatershed within a zone. Because the zones were delineated to capture a region

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[19] Total irrigated acreage data are from: MLJ-LLC. 2017. Annual Report October 2015-September 2016. Irrigated Lands Regulatory Program Central Valley Regional Water Quality Control Board. May 17, 2017. Table 2 (p. 8). An updated spreadsheet of irrigated acreage upstream of primary Core sites was provided by MLJ-LLC on December 20, 2017.

[20] MLJ-LLC. 2015. Revised Surface Water Quality Management Plan. Irrigated Lands Regulatory Program Central Valley Regional Water Quality Control Board. Resubmitted March 10, 2015. P.81

with similar hydrology, crop types, land use, soil types, and rainfall, water quality at Represented sites is expected to be similar to water quality at Core sites.

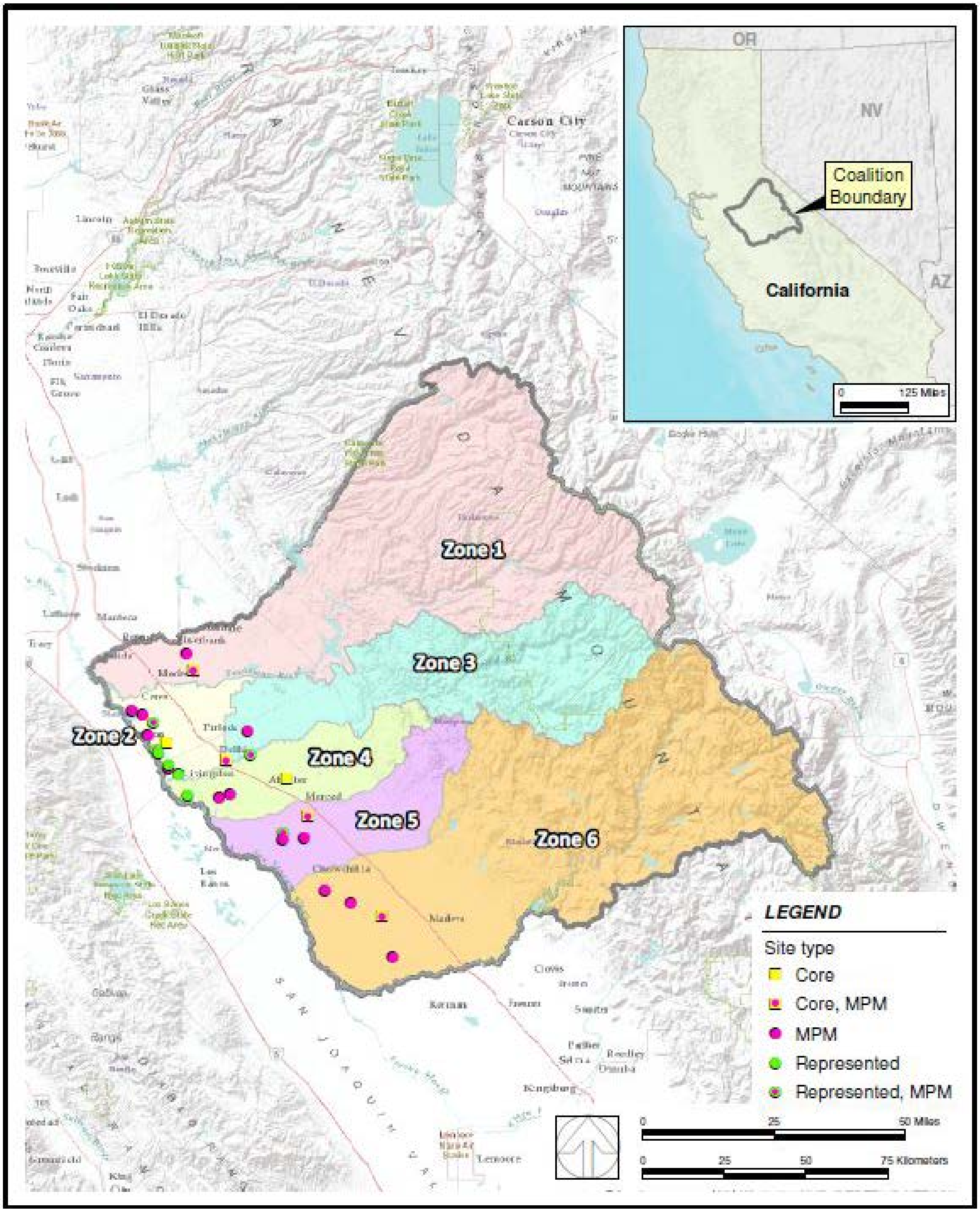

Figure 3-3. Coalition and zone boundaries. Locations of Core, Management Plan Monitoring (MPM), and Represented sites are indicated.

Within each zone, the program monitors one Core site monthly for two consecutive years, after which monitoring rotates to the alternate Core site for the subsequent two consecutive years. Core sites are monitored for physical parameters, nutrients, bacteria, pesticides, metals, water column toxicity, and sediment toxicity, to assess water quality and toxicity through the range of agricultural conditions within a year.[21] Monitoring at Represented sites occurs after an exceedance of a WQTL occurs at an associated Core site; Represented sites are then sampled for the parameter(s) that exceeded the WQTL. Sampling at Represented sites is conducted when water quality impacts are believed to be most likely (i.e., during months in which exceedances were previously observed at Core sites or months with the highest pesticide use). Represented sites are monitored for two years to characterize water quality under a range of agricultural and weather conditions.

In the event of WQTL or toxicity threshold exceedances, the Coalition hosts targeted outreach and education activities. In general, Coalition representatives inform members of progress in achieving water quality goals, discuss site subwatershed-specific monitoring results, and review proven, effective, best management practices to reduce discharge of contaminants. This information is shared through mailings, large grower meetings, workshops, meetings conducted by the County Agricultural Commissioners, and individual grower meetings.[22]

When two or more exceedances occur at the Core site within a three-year period, or when there is a single exceedance of a total maximum daily load (TMDL) constituent (specific conductivity, boron, chlorpyrifos, and diazinon), then Management Plan Monitoring (MPM) is initiated in the subwatershed where the exceedance occurred. Management Plans are designed to identify the potential source of a water quality problem, identify MPs that can be implemented to address the exceedances, develop an MP implementation schedule and performance goals, and develop a process and schedule to evaluate MP effectiveness. The comprehensive Surface Water Quality Management Plan, which explains the strategy for addressing exceedances of

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[21] MLJ-LLC. 2017. Annual Report October 2015-September 2016. Irrigated Lands Regulatory Program Central Valley Regional Water Quality Control Board. May 17, 2017. Table 11 (p.39).

[22] MLJ-LLC. 2017. Annual Report October 2015-September 2016. Irrigated Lands Regulatory Program Central Valley Regional Water Quality Control Board. May 17, 2017.

specific constituents, is approved by the Regional Board, and specific timelines for monitoring and outreach are identified in the Coalition's Annual Report.

Additional monitoring is also conducted to address special projects as they arise. Special projects are designed to evaluate the effects of specific commodities and/or MPs or evaluate sources of water quality impairment. For example, in 2016, a special project evaluated diazinon and chlorpyrifos and TMDL compliance within the Coalition region.

In addition to the Core and Represented site monitoring, MPM, and special projects sampling, storm events are targeted for sampling every year to characterize water quality during the highest flow periods, which have the greatest potential for offsite transport of pesticides, sediment, and other water quality parameters.

The current monitoring program included over 150 water samples collected from 26 locations across the six zones for water year (WY) 2016 (the most recent complete sampling period for which data are available). This sample count is an underestimate of sampling, because in many locations, no water was present and no sample could be collected by field personnel. In 2016, field personnel observed dry conditions at 40 sites.

3.2.3 Pesticide Monitoring

A comprehensive process is employed to select relevant pesticides for monitoring. In 2014, the Central Valley RWQCB staff organized a panel of scientists to develop a pesticide evaluation protocol (PEP). The Irrigated Lands Regulatory Program (ILRP) PEP is described as follows:

> The key steps in the [PEP] (Figure 1 [shown below as Figure 3-4]) involve acquiring pesticide use data, identifying the pesticides used in the watershed area under evaluation, creating ranking lists based on aquatic life and human health reference values, evaluating existing monitoring data, evaluating environmental fate factors, determining if analytical methods are available, prioritizing pesticides for monitoring, and submitting a pesticides monitoring proposal in the annual Monitoring Plan Update. In general, the scale of analysis will be a watershed area or

> areas that are associated with a given monitoring site. Central Valley Water Board staff will review and discuss the pesticide monitoring.[23]

The PEP begins by compiling data on chemical use, toxicity, degradation products and impurities and by organizing the information to compute the total amount of each pesticide applied within a zone. Once this is complete, the PEP involves calculating a preliminary ranking (Step 2 in Figure 3-4) that evaluates the relative risk for both aquatic life and human health for each chemical. The aquatic life (AQL) risk is calculated as the ratio of the amount of chemical applied (for each chemical on the cumulative monthly average use list) to the AQL reference value for that chemical. Similarly, the human health risk is calculated in the same manner but using the human health reference value. Chemicals are then excluded from monitoring, as shown in Steps 3–6 of Figure 3-4, if they are unlikely to pose an AQL risk because there exist sufficient data to show the chemicals are not present in concentrations that pose a risk; the chemicals are unlikely to be found in water; there are no analytical methods for the chemicals; or for site-specific reasons. The chemicals remaining are then prioritized and placed on the list for proposed monitoring. In this manner, the Coalition’s monitoring program is refined annually using three years of data on pesticide use; information on the risk posed by each chemical; information from ambient receiving water monitoring; and information on the chemical properties and environmental fate of each chemical.

Thus, pesticide monitoring is targeted each year to evaluate the pesticides in use over the most recent three years of record in each area and to focus efforts on those that are most likely to cause water quality or toxicity effects. The PEP is implemented annually, beginning in October 2017 (i.e., the beginning of water year 2018) and the proposed pesticide monitoring program and schedule for the following year is submitted with the annual monitoring plan update for review by the RWQCB.

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[23] Central Valley RWQCB. 2016. Prioritizing and Selecting Pesticides for Surface Water Monitoring. Central Valley Water Board, Irrigated Lands Regulatory Program. p. 2.

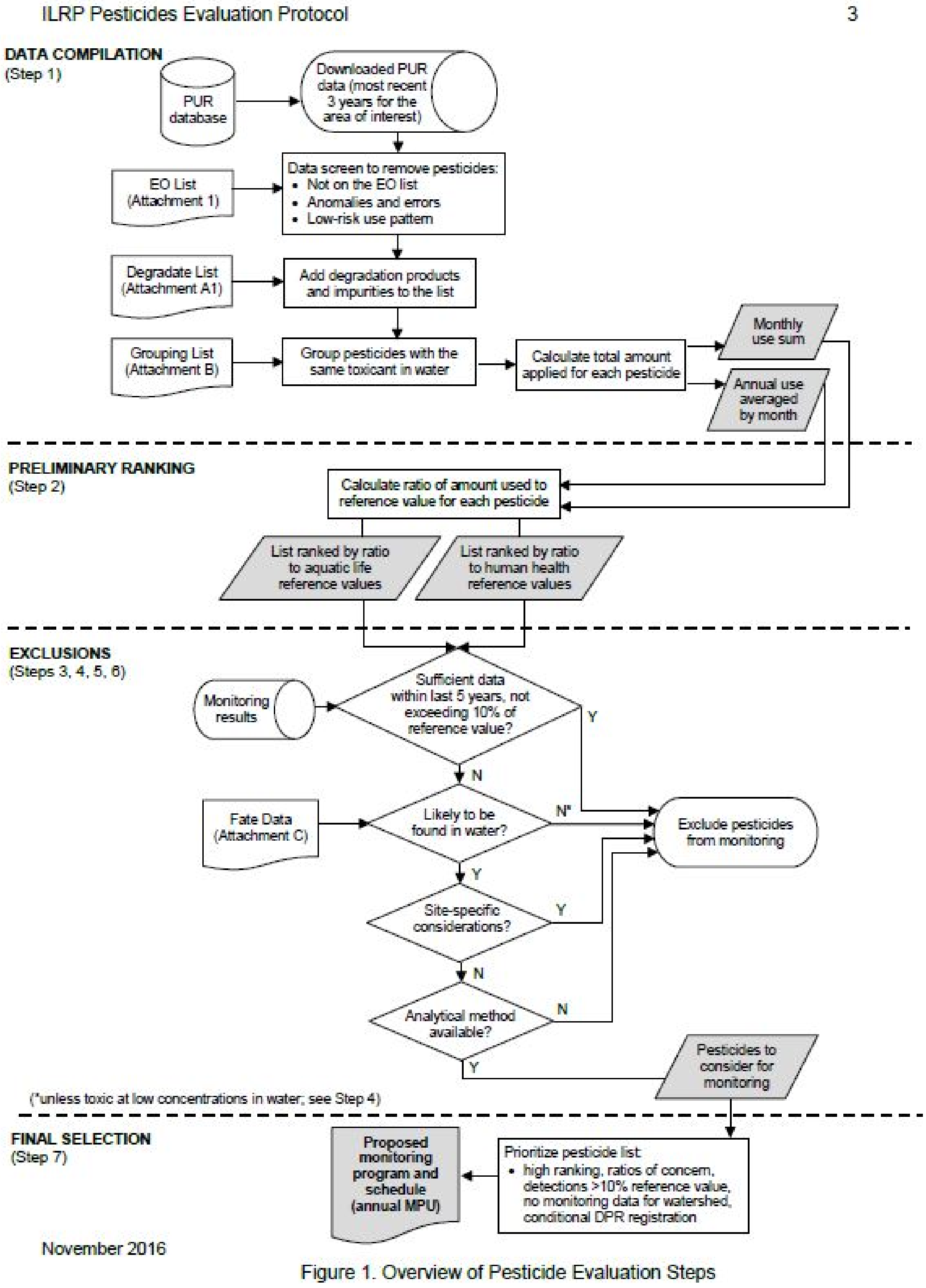

Figure 3-4. Reproduced Figure 1 “Overview of Pesticide Evaluation Protocol Steps”[24]

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[24] Ibid. p. 5.

4 Opinions based on Analysis of Available Data

4.1 Introduction

As detailed above, extensive monitoring has been conducted since 2004. Table 4-1 presents an aggregate summary of the monitoring data available from the Coalition monitoring program since 2004. Water was collected at 51 locations within the six zones, resulting in 1,870 water monitoring samples (excluding field replicates). Water samples were analyzed for up to 80 constituents, including metals, pesticides, and pyrethroids; up to three water toxicity tests; and nutrients, *E. coli*, and physical measurements. Table 4-2 lists the constituents of the monitoring program together with the total number of measurements obtained since 2004 for each constituent. Although the monitoring design has changed over time, these data, together with information on land use, topography, soil types, vegetation, and MPs, form the basis of Exponent's evaluation of water quality, water quality trends, and implementation program effectiveness.

Table 4-1. Number of monitoring locations and number of samples measured within each zone since 2004

Zone	Number of sites sampled	Number of water samples analyzed
Zone 1	6	194
Zone 2	14	497
Zone 3	4	224
Zone 4	11	389
Zone 5	7	373
Zone 6	9	193

Table 4-2. List of constituents and the number of water column measurements since 2004

Category	Analyte	Result Count
Metals	Arsenic, Total	617
	Boron, Total	772
	Cadmium, Dissolved	235
	Cadmium, Total	566
	Copper, Dissolved	758
	Copper, Total	983
	Lead, Dissolved	356
	Lead, Total	634
	Molybdenum, Total	272
	Nickel, Dissolved	400
	Nickel, Total	731
	Selenium, Total	692
	Zinc, Dissolved	449
	Zinc, Total	784
Pesticides	Aldrin	158
	Azinphos Ethyl	5
	Bolstar	5
	Chlordane	158
	Coumaphos	5
	Cyfluthrin, Total	429
	Endosulfan I	158
	Endosulfan II	158
	EPN	5
	EPTC	5
	Esfenvalerate/Fenvalerate, Total	519
	Ethion	5
	Ethoprop	5
	Fenamiphos	5
	Fenchlorphos	5
	Fensulfothion	5
	Fenthion	5
	HCH, alpha-	158
	HCH, beta-	158
	HCH, delta-	158
	HCH, gamma-	158
	Heptachlor	158
	Heptachlor Epoxide	158
	Merphos	5
	Mevinphos	5

Category	Analyte	Result Count
	Molinate	441
	Naled	5
	Parathion, Ethyl	5
	Pendimethalin	5
	Permethrin, cis-	4
	Permethrin, trans-	4
	Tetrachlorvinphos	5
	Thiobencarb	443
	Tokuthion	5
	Toxaphene	158
	Tributyl Phosphorotrithioate, S,S,S-	5
	Trichloronate	5
Pesticide/Carbamates	Aldicarb	1084
	Carbaryl	1084
	Carbofuran	1102
	Methiocarb	1084
	Methomyl	1084
	Oxamyl	1084
Pesticide/Herbicides	Atrazine	1084
	Cyanazine	1097
	Diuron	1147
	Glyphosate	626
	Linuron	1084
	Paraquat	626
	Simazine	1097
	Trifluralin	653
Pesticide/Organochlorines	DDD(p,p')	609
	DDE(p,p')	609
	DDT(p,p')	609
	Dicofol	609
	Dieldrin	609
	Endrin	609
	Methoxychlor	609
Pesticide/Organophosphates	Azinphos Methyl	1103
	Chlorpyrifos	1572
	Demeton-s	667
	Diazinon	1356
	Dichlorvos	667
	Dimethoate	1153
	Disulfoton	1108
	Malathion	1113

Category	Analyte	Result Count
	Methamidophos	1100
	Methidathion	1103
	Parathion, Methyl	1108
	Phorate	1108
	Phosmet	1103
Pyrethroid	Bifenthrin	431
	Cyhalothrin, Total lambda-	519
	Cypermethrin, Total	519
	Permethrin, Total	519
Water Tox	Ceriodaphnia dubia survival	1374
	Pimephales promelas survival	1289
	Selenastrum capricornutum total cell count	1513
Nutrients	Ammonia as N	1223
	Nitrate + Nitrite as N	870
	Nitrate as N	380
	Nitrite as N	372
	Nitrogen, Total Kjeldahl	771
	OrthoPhosphate as P, Dissolved	1076
	Phosphorus as P	920
Pathogens	E. coli	1355
Physical Parameters	BOD	92
	Color	565
	Discharge	1540
	Hardness as CaCO3, Dissolved	748
	Hardness as CaCO3, Total	456
	Oxygen, Dissolved	2210
	Oxygen, Saturation	10
	pH	2210
	SpecificConductivity	2209
	Temperature	2210
	Total Dissolved Solids	1164
	Total Organic Carbon	1416
	Total Suspended Solids	852
	Turbidity	1417
	Velocity	77

Although the Coalition analyzes surface water samples for a comprehensive list of constituents, Exponent’s analysis has focused on three to examine and illustrate the approach of the monitoring program. As detailed below, our analysis focused on chlorpyrifos, which is used only in irrigated agriculture; *Ceriodaphnia dubia* (*C. dubia*), the toxicity test believed to be most responsive to agricultural signals; and dissolved copper, which originates from multiple sources in addition to irrigated agriculture.

Chlorpyrifos reflects the direct effect of focused outreach efforts because it is a regulated product used only by permitted growers. Chlorpyrifos is water soluble and persistent in the environment. It is an organophosphate pesticide used on a wide variety of crops in California and can both bind to sediment and remain in the water column ($K_{ow} = 4.7$).[25] The WQTL to protect aquatic life is 0.015 µg/L.[26] Chlorpyrifos is used year-round to control pests such as ants, mites, moths, scale, and worms, and it can only be purchased by persons who hold a restricted materials permit issued by the local County Agriculture Commissioner.[27] Because agriculture is the only source of chlorpyrifos to the environment, it was chosen as an exemplar for analyzing the efficacy of the Coalition's outreach program on water quality.

C. dubia toxicity can be tied directly to chlorpyrifos, as 50% mortality (LC_{50}) occurs at 0.055 µg/L chlorpyrifos.[28] Although the Coalition monitors water column toxicity for *Selenastrum capricornutum* and *Pimephales promelas* as well, *S. capricornutum* toxicity is measured as total cell count, which makes assessing MPs more challenging, and toxicity in *P. promelas* has occurred less frequently in Coalition samples than for *C. dubia*, such that it is more difficult to discern the impacts of management actions.

Other water quality constituents monitored by the Coalition, such as dissolved copper, have multiple sources, including many unrelated to agricultural uses. Thus, receiving water concentrations vary as a function of multiple factors, many of which are outside the control of

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[25] National Pesticide Information Center: http://npic.orst.edu/factsheets/archive/chlorptech.html

[26] Sacramento/San Joaquin Rivers Basin Plan: Page III-6.01

[27] MLJ-LLC. 2017. Annual Report October 2015—September 2016. Prepared by MLJ-LLC for the East San Joaquin Water Quality Coalition under the Irrigates Lands Regulatory Program. Submitted to the Central Valley Regional Water Quality Control Board. May 1, 2017. p.91.

[28] MLJ-LLC. 2017. Annual Report October 2015–September 2016. Irrigated Lands Regulatory Program Central Valley Regional Water Quality Control Board. Submitted May 1, 2017. p. 91.

Coalition members. Copper-containing herbicides are a common source of copper to irrigated lands, and copper also occurs naturally in soils and is present in the environment from anthropogenic sources, such as automobile brake pad wear,[29] metal and electrical manufacturing (copper pipes), and algae control.[30] The WQTL for dissolved copper varies as a function of the hardness of the receiving water.

4.2 Core and Represented monitoring sites provide sufficient spatial coverage.

Exponent used information and data provided by MLJ-LLC to evaluate the representativeness of the Core and Represented sites. Exponent used shapefiles provided by MLJ-LLC to calculate the area of land in the Coalition, and the individual zones and watersheds and to evaluate land-use distributions. Core and Represented site monitoring locations, subwatersheds, and zone boundaries are shown in Figure 4-1. In addition, Exponent downloaded cropland data layers from the United States Department of Agriculture (USDA) National Agriculture Statistics Service for land use evaluations.[31]

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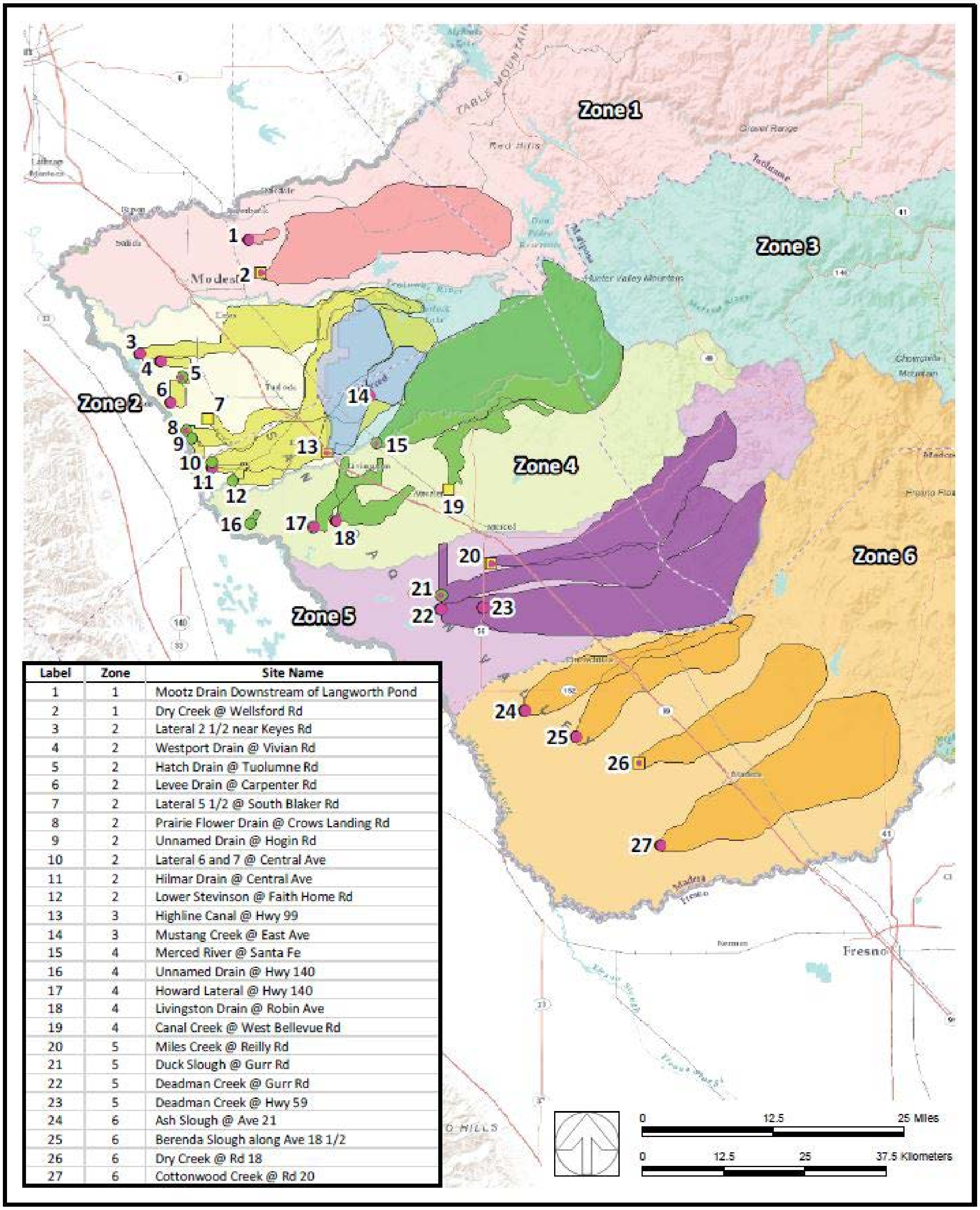
[29] For additional information, see https://www.dtsc.ca.gov/SCP/BrakePadLegislation.cfm.

[30] For additional information, see https://www.epa.gov/wqc/aquatic-life-criteria-copper#surface.

[31] Cropland data layers downloaded from https://nassgeodata.gmu.edu/CropScape/



Label	Zone	Site Name
1	1	Mootz Drain Downstream of Langworth Pond
2	1	Dry Creek @ Wellsford Rd
3	2	Lateral 2 1/2 near Keyes Rd
4	2	Westport Drain @ Vivian Rd
5	2	Hatch Drain @ Tuolumne Rd
6	2	Levee Drain @ Carpenter Rd
7	2	Lateral 5 1/2 @ South Blaker Rd
8	2	Prairie Flower Drain @ Crows Landing Rd
9	2	Unnamed Drain @ Hogin Rd
10	2	Lateral 6 and 7 @ Central Ave
11	2	Hilmar Drain @ Central Ave
12	2	Lower Stevinson @ Faith Home Rd
13	3	Highline Canal @ Hwy 99
14	3	Mustang Creek @ East Ave
15	4	Merced River @ Santa Fe
16	4	Unnamed Drain @ Hwy 140
17	4	Howard Lateral @ Hwy 140
18	4	Livingston Drain @ Robin Ave
19	4	Canal Creek @ West Bellevue Rd
20	5	Miles Creek @ Reilly Rd
21	5	Duck Slough @ Gurr Rd
22	5	Deadman Creek @ Gurr Rd
23	5	Deadman Creek @ Hwy 59
24	6	Ash Slough @ Ave 21
25	6	Berenda Slough along Ave 18 1/2
26	6	Dry Creek @ Rd 18
27	6	Cottonwood Creek @ Rd 20

Figure 4-1. Subwatersheds and monitoring locations. Core site locations used during 2016 are shown as yellow squares.

The six zones that compose the Coalition were delineated based on hydrology, crop types, land use, soil types, and rainfall. Monitoring locations (Core and Represented) were established at the downstream end of subwatersheds to evaluate the effects of land use and agricultural practices within each subwatershed on water quality. To better understand the zone boundaries, Exponent used land-use data provided by MLJ-LLC to rank the crop types by area in Zones 1 and 6[32] and the subwatersheds within those zones. The ranking evaluation showed that the top ten crops used within each zone (as a whole) compose over 95% of the total agricultural coverage (Table 4-3 and

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[32] Due to extensive overlap of subwatershed boundaries with zone boundaries in Zones 2 through 5, this analysis was only feasible for Zones 1 and 6 where the subwatershed boundaries fell within zone boundaries.

Table 4-4). Those same ten crops (unique to each zone) also compose over 95% of the irrigated lands within the subwatersheds within each respective zone (see full crop type coverage tables in Appendix B). Thus, agricultural land use within subwatersheds reflects each zone as a whole, such that Core and Represented sites are representative of the major crop types within a zone.

Table 4-3. Zone 1 crop type coverage for the entire zone and the two subwatersheds within Zone 1.

Crop	Zone 1		Dry Creek/Wellsford Road		Mootz Drainage	
	Acres	Percent	Acres	Percent	Acres	Percent
Almonds	43484	43.3	11108	50.0	311	27.9
Alfalfa	12816	12.8	1695	7.6	428	38.4
Other Hay/Non Alfalfa	12742	12.7	3678	16.5	199	17.8
Walnuts	10303	10.3	928	4.2	6	0.6
Grapes	9747	9.7	3108	14.0	63	5.7
Corn	1984	2.0	190	0.9	9	0.8
Oats	1962	2.0	328	1.5	4	0.3
Winter Wheat	1307	1.3	430	1.9	51	4.6
Fallow/Idle Cropland	1174	1.2	144	0.7	7	0.6
Dbl Crop Oats/Corn	1144	1.1	93	0.4	2	0.2
Sum	96663	96	21701	98	1080	97

Table 4-4. Zone 6 crop type coverage for the entire zone and the four subwatersheds within Zone 6.

Crop	Zone 6		Ash Slough		Berenda Slough		Cottonwood Creek		Dry Creek	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Almonds	137028	37.7	8835	41.4	12546	58.0	12020	30.1	7935	36.4
Grapes	107784	29.6	3774	17.7	4451	20.6	16947	42.4	7267	33.4
Alfalfa	26733	7.4	2908	13.6	397	1.8	503	1.3	301	1.4
Pistachios	18167	5.0	544	2.6	658	3.0	1713	4.3	801	3.7
Fallow/Idle Cropland	17114	4.7	1432	6.7	1792	8.3	2376	6.0	1164	5.3
Winter Wheat	14146	3.9	655	3.1	399	1.9	890	2.2	501	2.3
Oranges	9924	2.7	312	1.5	437	2.0	1281	3.2	2175	10.0
Dbl Crop WinWht/Corn	7168	2.0	667	3.1	111	0.5	10	0.0	70	0.3
Walnuts	6836	1.9	154	0.7	208	1.0	2338	5.9	710	3.3
Tomatoes	3803	1.0	742	3.5	99	0.5	131	0.3	6	0.0
Sum	348701	96	20023	94	21098	98	38210	96	20930	96

The Coalition covers almost 5.6 million acres, with nearly one million acres of irrigated lands (Table 3-1). Zones 1 and 6 cover the most area, composing nearly 60% of the footprint of the Coalition. Only 6% of the land area in Zone 1 is cropland, and 89% of the area in Zone 1 is undeveloped. Zone 2 is the smallest by land area but is 75% cropland (Table 4-6); in addition, Zone 2 has the highest percentage of farmers who are not Coalition members and who do not receive outreach. Zones 4 and 5 are the most similar in size and land-use distribution. Zone 6 has the largest footprint and the most cropland of all the zones.

Table 4-5. Total land area of the six zones that compose the Coalition by land use

Land Use	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Developed[a] (acres)	69,431	32,684	13,369	29,297	17,946	55,292
Undeveloped[b] (acres)	1,583,242	13,052	763,273	189,372	214,972	1,571,732
Cropland (acres)[c]	100,550	147,768	69,521	118,987	163,273	363,939
Other[d] (acres)	33,453	2,297	11,566	1,282	326	23,169
Sum (acres)	1,786,676	195,801	857,729	338,938	396,517	2,014,132

Notes: Acreage was calculated USDA cropland data layers downloaded from https://nassgeodata.gmu.edu/CropScape/. These values differ slightly from the data presented in Table 3-1 due to the use of a different data source

[a] Developed (non-agriculture) land includes various types of residential, industrial, or municipal developed land.

[b] Undeveloped land includes, for example, forested areas, shrubland, grass/pastures, and wetlands.

[c] Cropland includes irrigated lands.

[d] Other includes open water and barren land.

Table 4-6. Distribution of land in the six Coalition zones by land use percentages

Land Use	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Developed	4	17	2	9	5	3
Undeveloped	89	7	89	56	54	78
Cropland	6	75	8	35	41	18
Other	2	1	1	0	0	1
Fraction of cropland upstream of monitoring locations[a]	23	NA	NA	NA	NA	29

[a] Sum of the subwatershed areas within each zone that are tributary to a monitoring location. Because hydrologic boundaries of some subwatersheds cross-zone boundaries in Zones 2 through 5, this value was not calculated for these zones.

The subwatersheds in Zones 1 and 6 fall entirely within the zone boundaries, and land use is widely distributed between agricultural, developed, and natural, unaltered land (Figure 4-2 and Figure 4-3). In some cases, the subwatersheds that drain to monitoring sites in Zones 2 through 5 overlap zone boundaries (Figure 4-1) because subwatersheds were delineated based on hydrologic watershed boundaries. In subwatersheds that drain land areas within two zones, exceedances of WQTLs may result from MPs or environmental conditions in either zone.

However, outreach occurs at the watershed level, such that farms in a subwatershed upstream of an exceedance of WQTLs are targeted for outreach, regardless of zone boundaries.

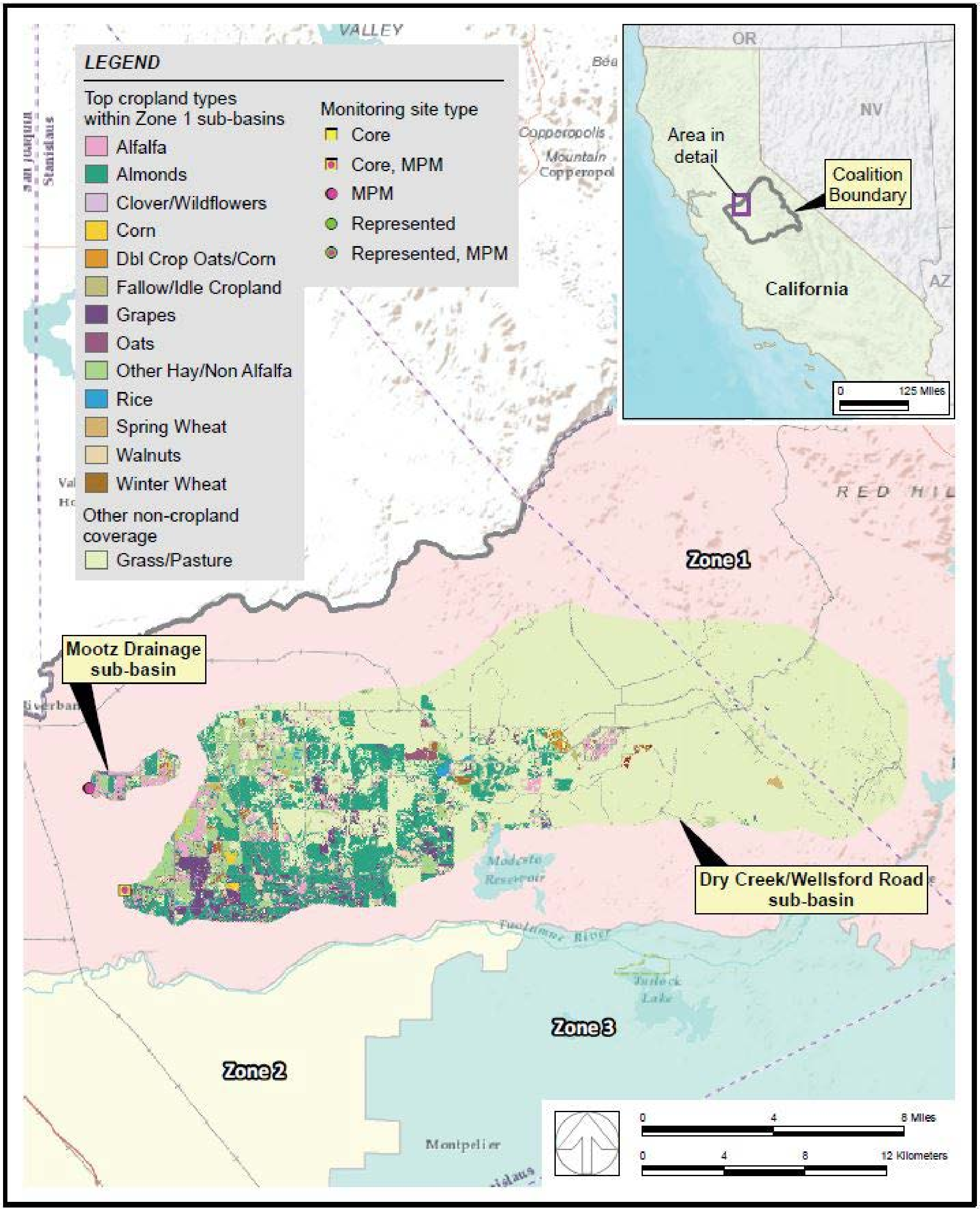

Figure 4-2. Zone 1 subwatershed crop type distribution

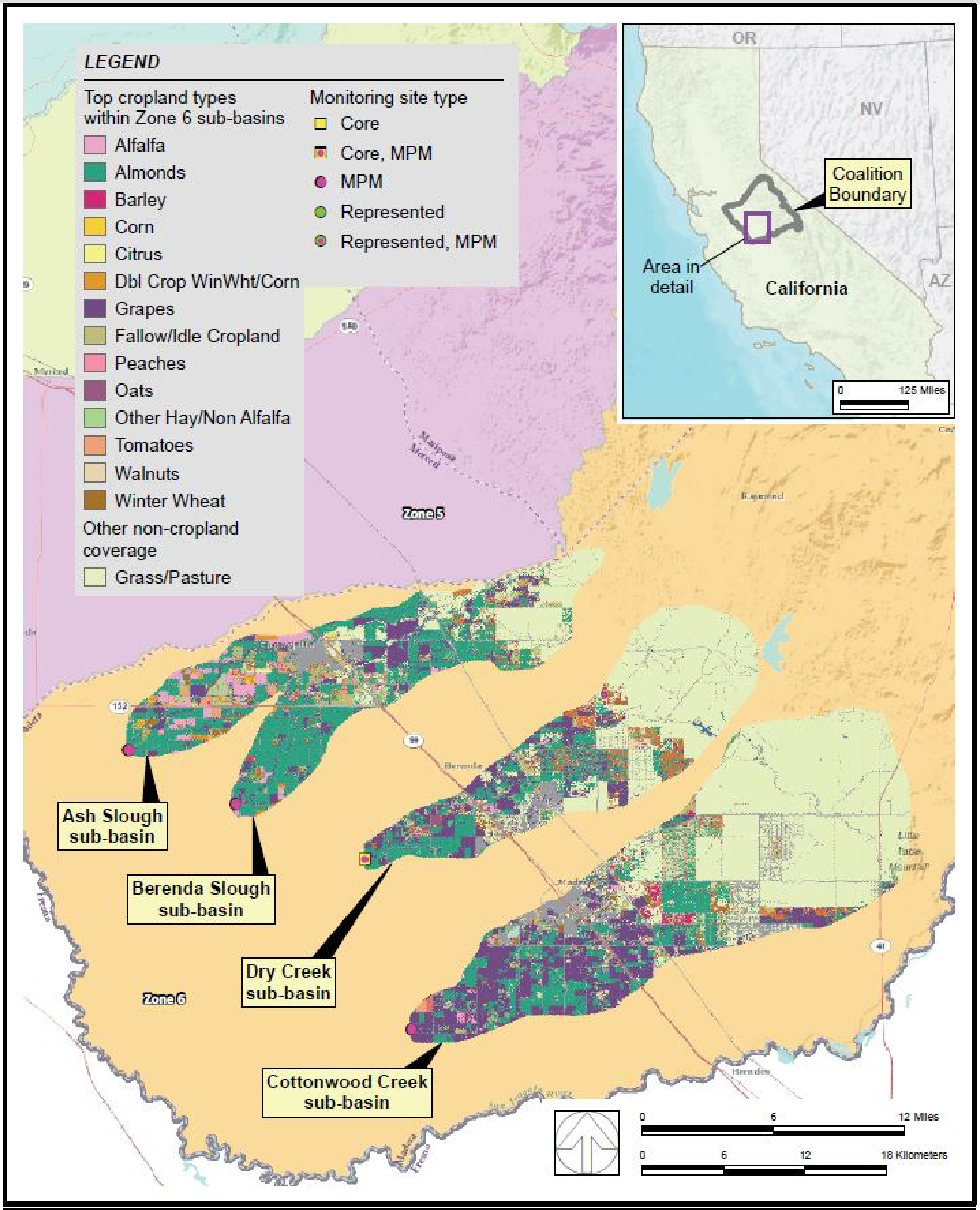

Figure 4-3. Zone 6 subwatershed crop type distribution

The monitoring stations (Core and Represented) in Zones 1 and 6 capture drainage from 23% and 29%, respectively, of the irrigated lands from each zone (Table 4-6). Because some of the subwatershed areas overlap in the other zones, this value was not calculated for Zones 2 through 5. Coalition-wide, the Core and Represented site subwatersheds cover over 2.7 million acres, or nearly half of the entire Coalition area, of which less than one million acres are considered irrigated lands. The subwatersheds that drain to the Core sites alone capture about 15% of the total area of irrigated lands within the Coalition boundary.

To characterize water quality in receiving waters and to evaluate the effects of management actions on receiving water quality, samples are collected in flowing water that could convey pesticides downstream. Conditions within the Coalition area are frequently dry in the dry season, and field personnel visit each sampling site as scheduled but do not collect water samples when water is absent. Based on our review of the Coalition area and discussion with MLJ-LLC, we concur that sampling of the Core sites provides a consistent and appropriate measure of receiving water quality and of the impacts of practices on irrigated lands to receiving water quality.

4.3 The monitoring program has produced data that identify changes in water quality over time and confirm that management practices on irrigated lands have improved water quality over time.

The monitoring program is designed to provide a consistent measure of water quality over time to assess the effects of changes in agricultural practices on water quality within the Coalition area. Trends in water quality are affected by irrigation water demand and sources, crop seasonality, site MPs, and additional factors unrelated to agricultural practices such as rainfall and temperature. The current program consistently measures a targeted list of constituents at one Core site for two years in each zone. As noted in Section 4.2, the Core sites were designated after careful review of subwatershed characteristics (including hydrology, crop types, land use, soil types, crop diversity, monitoring history and duration, subwatershed acreage) and represent locations that consistently have flowing water and are safe for sampling. Sampling at Represented sites provides additional information on factors that may play a role in exceedances observed at Core sites, such as pesticide usage and other agricultural practices, and provides additional information to evaluate the impact of outreach efforts on observed exceedances.

To evaluate trends over time and the effectiveness of MPs, water quality data were used to calculate the rate at which WQTLs were exceeded each monitoring year. Exceedance rates were plotted by monitoring year and divided into three periods based on outreach type: *Before Focused Outreach* (pre-2009), *Focused Outreach Initiated* (2009–2013), and *Current Monitoring Program* (WYs 2014–2017). Note that samples not collected because sampling locations were dry were not counted when calculating exceedance rates even though, by definition, these conditions could not produce an exceedance of WQTLs. Only monitoring sites with samples collected in at least two of the three outreach periods were included in this analysis.

Figure 4-4 through Figure 4-9 show exceedance rates for chlorpyrifos, which, as detailed in Section 4.1, is the constituent most closely associated solely with agricultural practices. Similar figures for other constituents with one or more exceedances are included in Appendix C. Exceedance rates for chlorpyrifos have generally declined over time, apparently as a result of focused outreach, with several zones showing no or low exceedance percentages in the most recent monitoring period (see Table 4-7). Zone 2 does not follow this general pattern, which likely reflects the larger fraction of agricultural operations that are not Coalition members and who do not receive outreach. Overall, the change in exceedance rates in the zones with the greatest area within the Coalition indicates the monitoring and outreach programs are successful and result in changes in management practices that improve water quality.

Table 4-7. Chlorpyrifos exceedance percentages by outreach type category

Outreach Period	Time Period	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Before Focused Outreach	2004–2008	20.0	8.0	15.1	11.9	9.1	16.0
Focused Outreach Initiated	2009–2013	5.4	4.8	3.6	1.3	8.2	3.4
Current Monitoring Program	WY 2014–2017	1.9	10.1	3.6	1.9	5.4	0

As discussed in 3.1.1, toxicity studies provide a direct measurement of water quality effects on aquatic life, and as such serve as an aggregate water quality indicator. Toxicity test results for *S. capricornutum* and *P. promelas* are included in Appendix C, but as detailed in Section 4.1, these are less ideal for assessing the effectiveness of management actions than *C. dubia*. Exceedance rates for *C. dubia* are shown in Figure 4-10 through Figure 4-15 and summarized in Table 4-8. Exceedance rates show a marked decline over time in Zones 1, 3, 4, and 6, all of which show no exceedances since 2008. Zone 5 has remained relatively unchanged, while the changes in Zone 2 likely reflect the larger fraction of agricultural operations that do not receive outreach from the Coalition because they are not subject to the irrigated lands WDRs and thus do not belong to the Coalition. The consistent trend of declining exceedance rates for chlorpyrifos and *C. dubia* toxicity demonstrate that the Coalition’s program of monitoring followed by targeted outreach is effective at reducing toxicity in receiving waters.

Table 4-8. *C. dubia* survival exceedance percentages by outreach type category

Outreach Period	Time Period	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Before Focused Outreach	2004–2008	5.7	2.9	14.0	11.3	5.6	2.6
Focused Outreach Initiated	2009–2013	0	6.8	0	0	7.8	0
Current Monitoring Program	WY 2014–2017	0	12.8	0	0	12.0	0

Exceedance rates for chlorpyrifos and *C. dubia* toxicity demonstrate that the Coalition’s program of monitoring followed by targeted outreach is effective in improving receiving water quality. In contrast, exceedances of the hardness-dependent WQTLs for dissolved copper occur frequently within zones where outreach appears to have been effective for other constituents (Figure 4-16 to Figure 4-18). Dissolved copper was not measured frequently before outreach initiation (only total copper was analyzed prior to water year 2009), but since 2009 annual exceedance rates have ranged up to 100% for zones 3, 4, and 6. Samples collected in Zones 1 and 2 have never exceeded the WQTL for dissolved copper, while samples from Zone 5 exceeded the WQTL only occasionally (5 out of 191 measurements). [For this reason, figures are not included for dissolved copper in samples collected from Zones 1 and 2.] Outreach efforts to Coalition members have not resulted in significant changes in exceedance rates for dissolved copper because there are many non-agricultural sources of copper and because water varies in hardness, affecting the WQTL used to evaluate exceedances. See also Section 4.4.

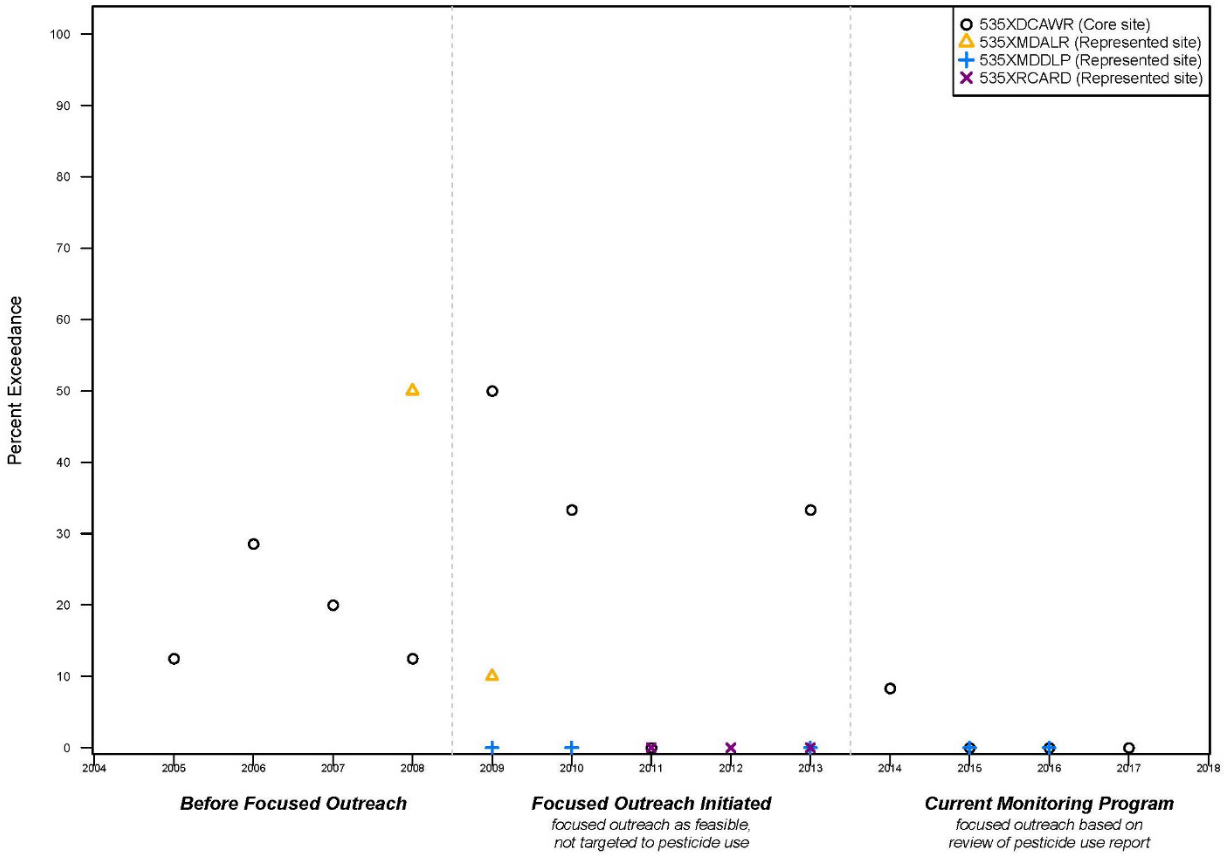

Figure 4-4. Annual exceedance rates for chlorpyrifos in Zone 1. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

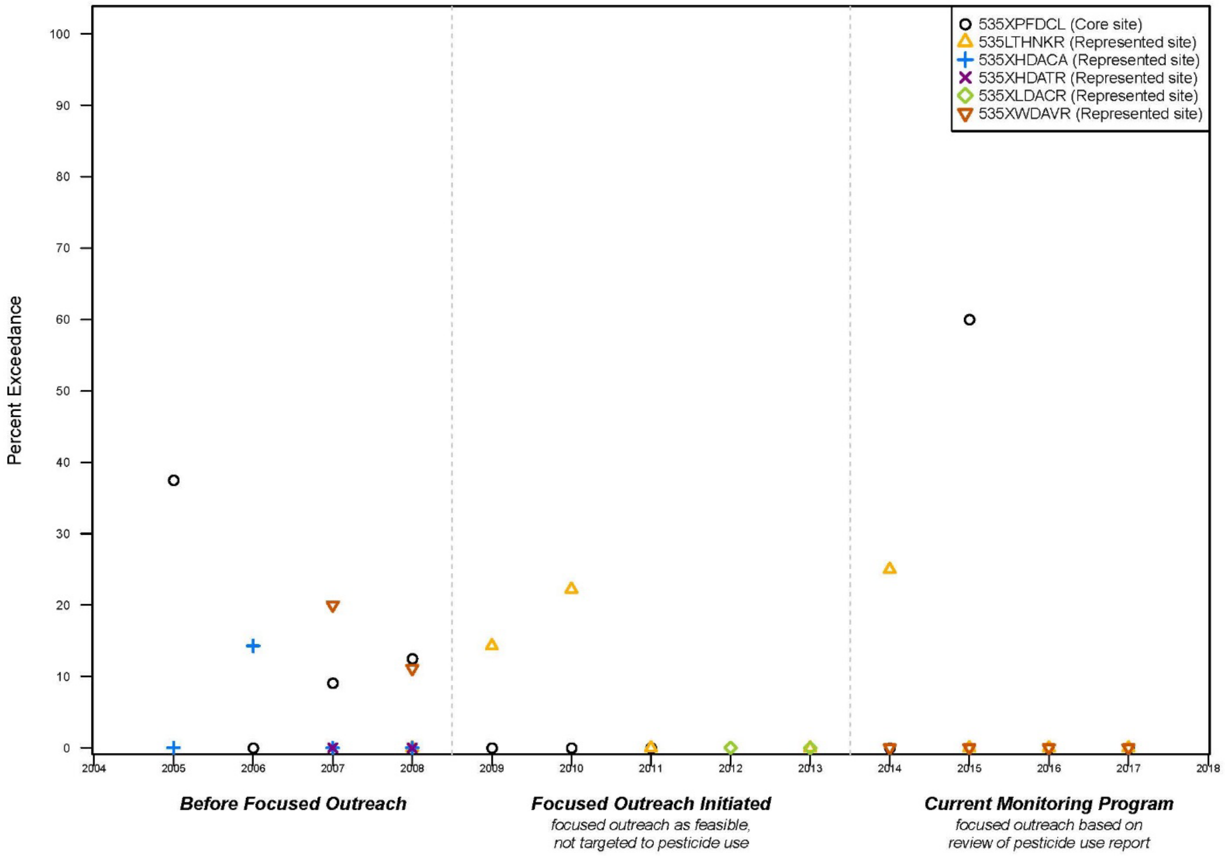

Figure 4-5. Annual exceedance rates for chlorpyrifos in Zone 2. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

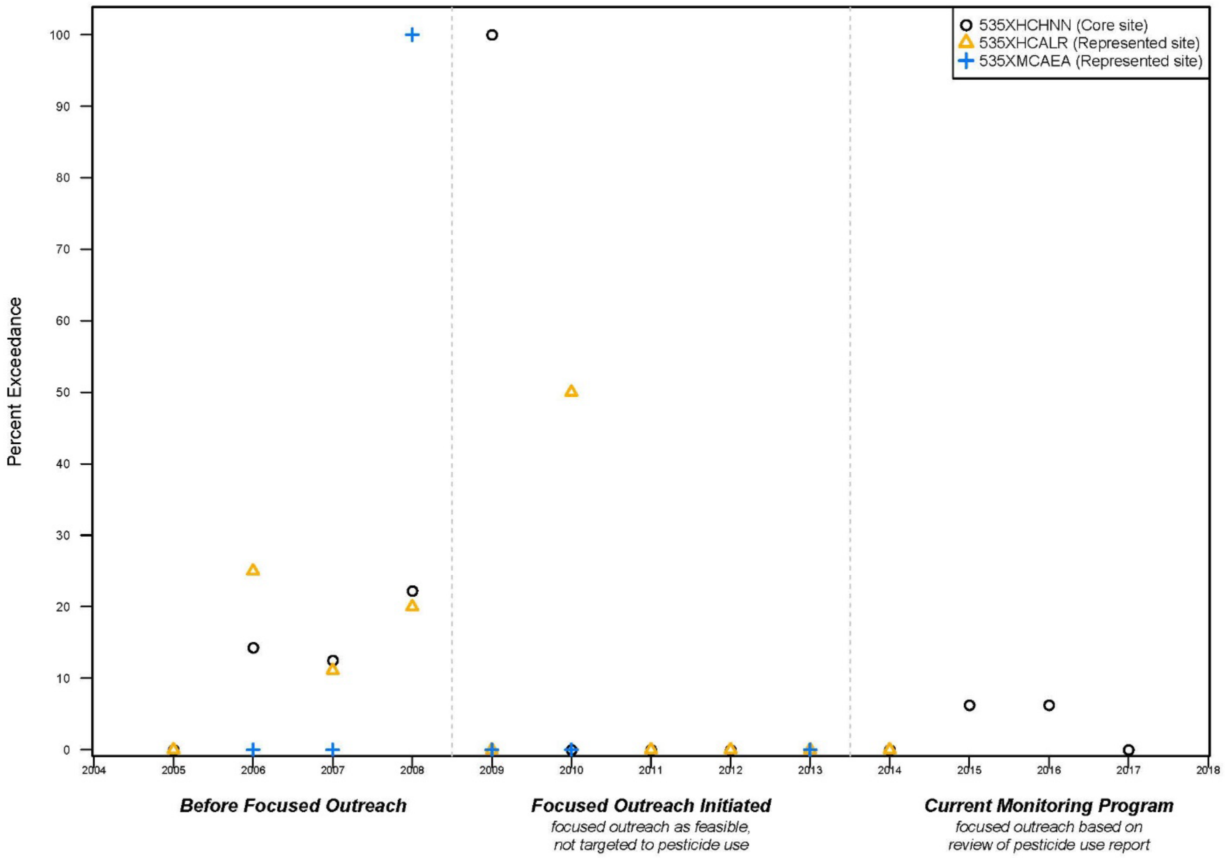

Figure 4-6. Annual exceedance rates for chlorpyrifos in Zone 3. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

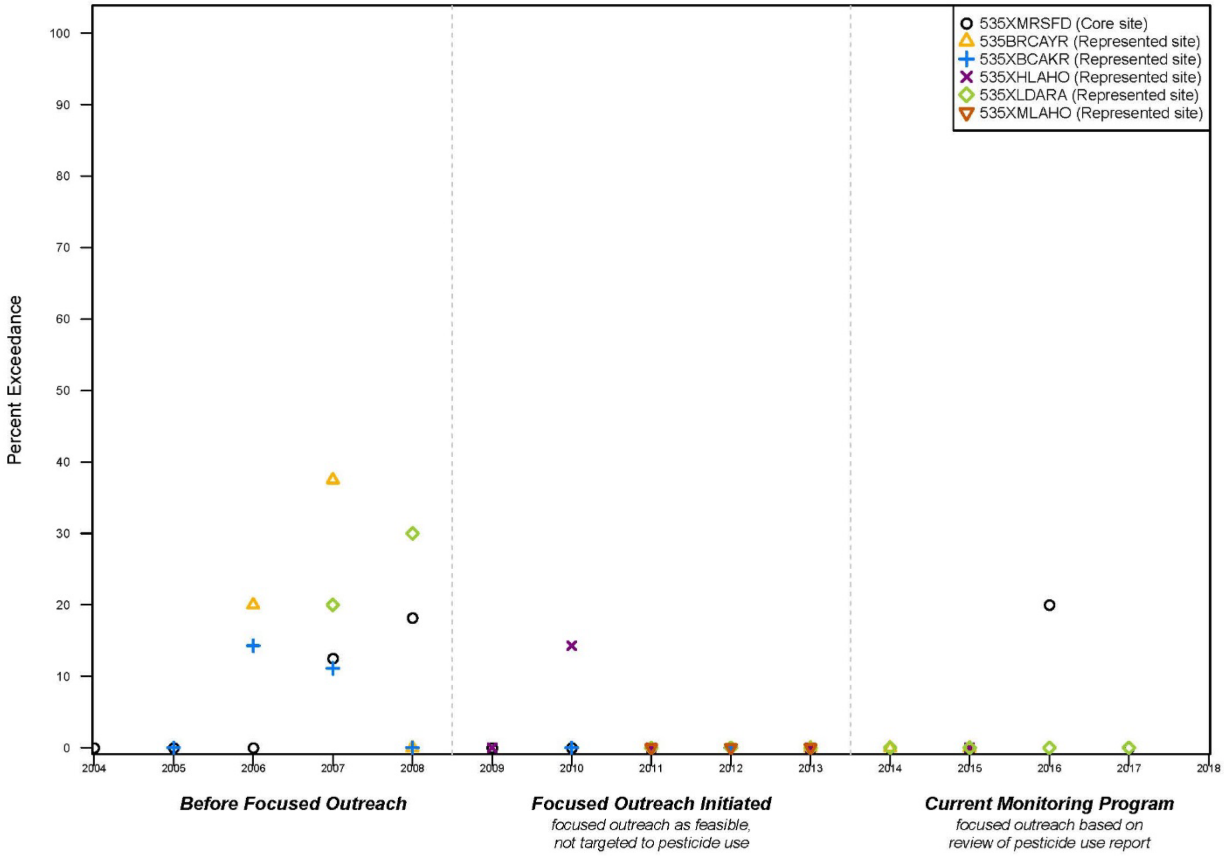

Figure 4-7. Annual exceedance rates for chlorpyrifos in Zone 4. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

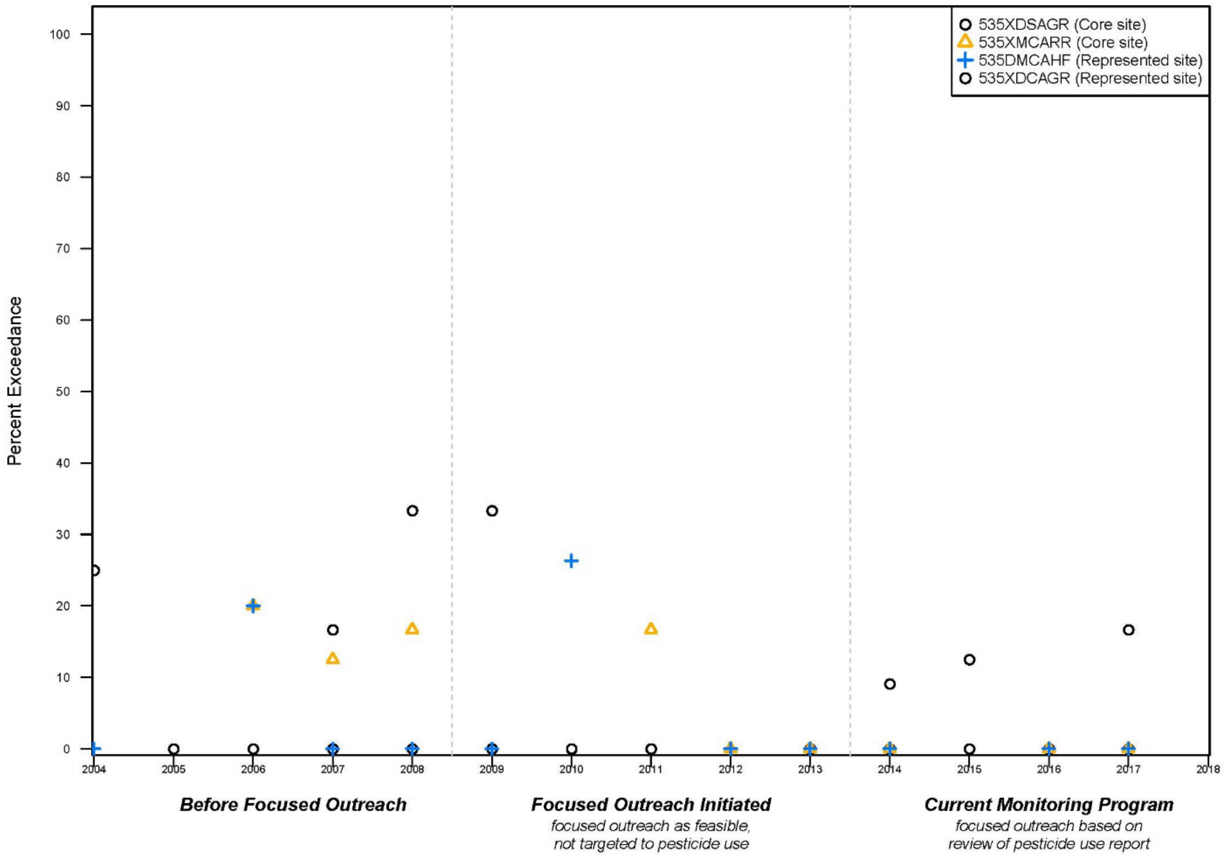

Figure 4-8. Annual exceedance rates for chlorpyrifos in Zone 5. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

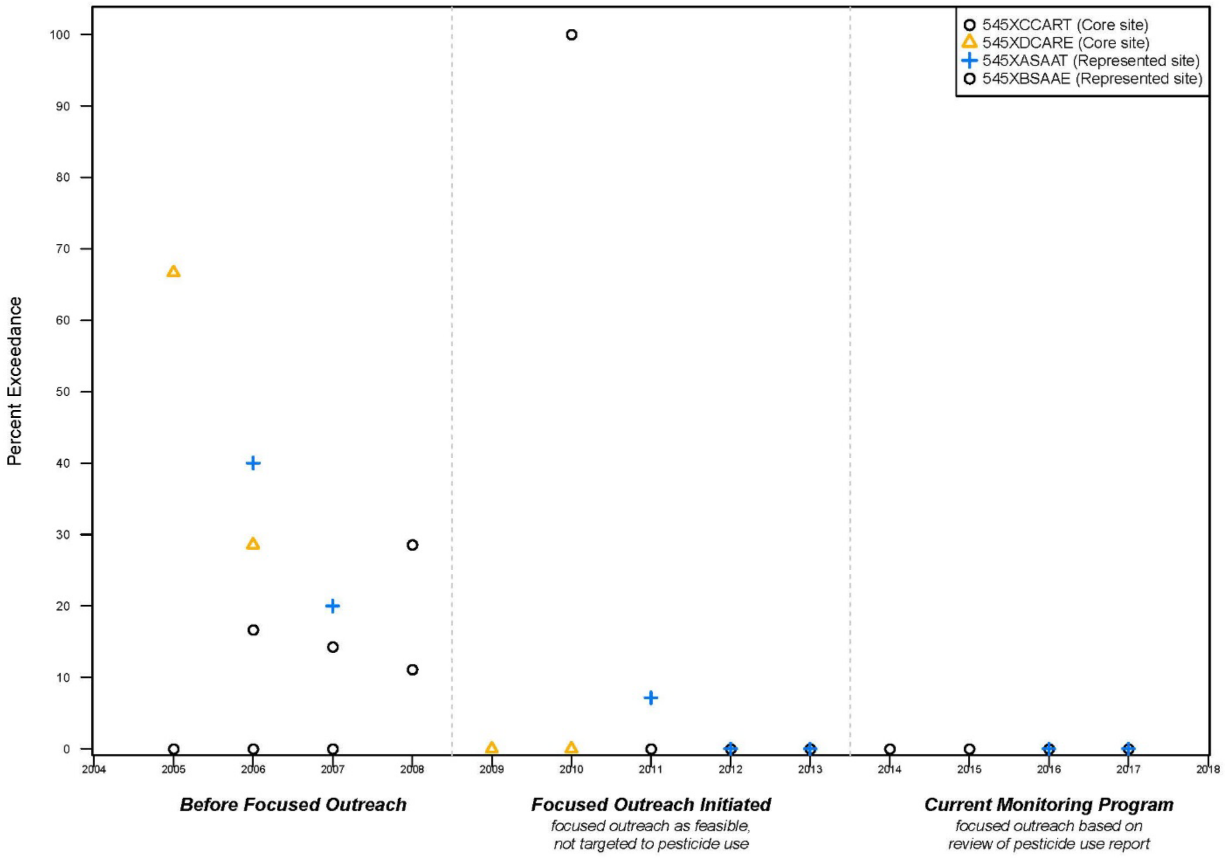

Figure 4-9. Annual exceedance rates for chlorpyrifos in Zone 6. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

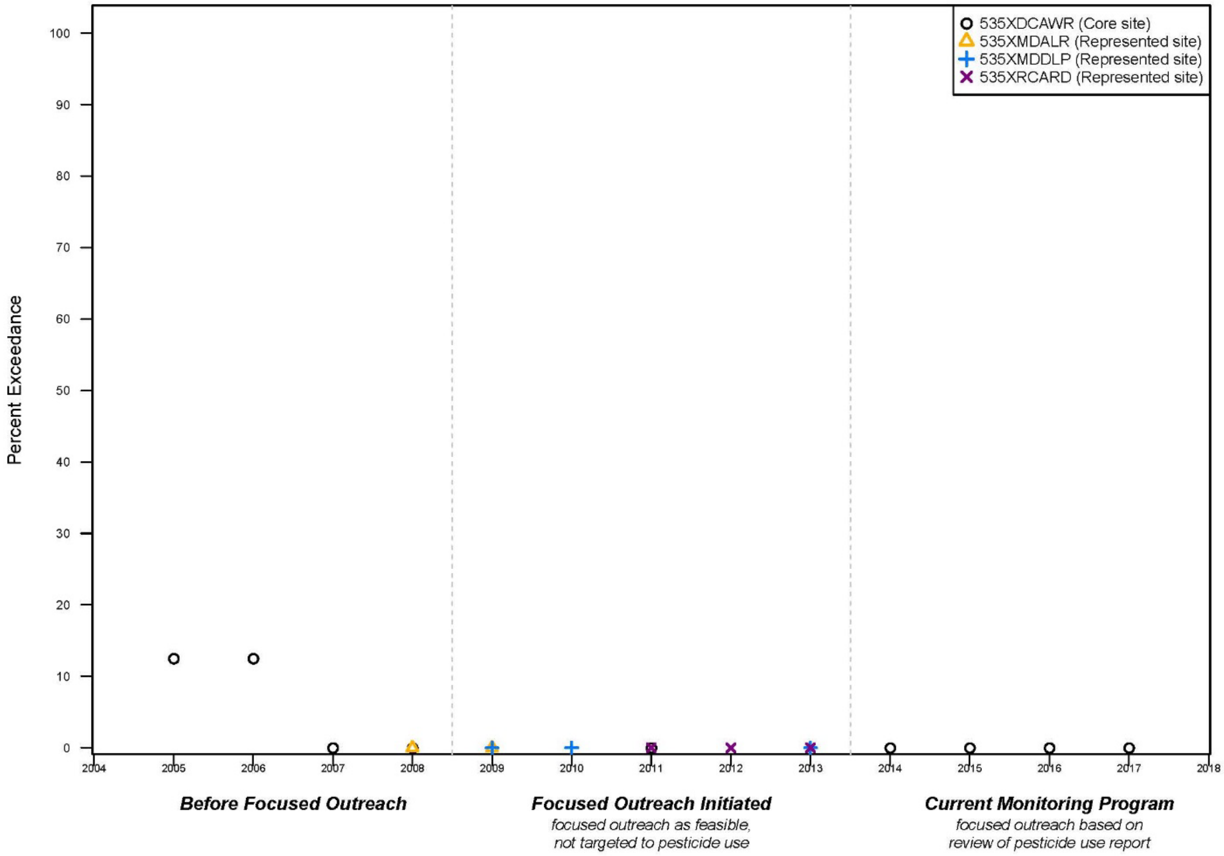

Figure 4-10. Annual exceedance rates for *Ceriodaphnia dubia* survival in Zone 1. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

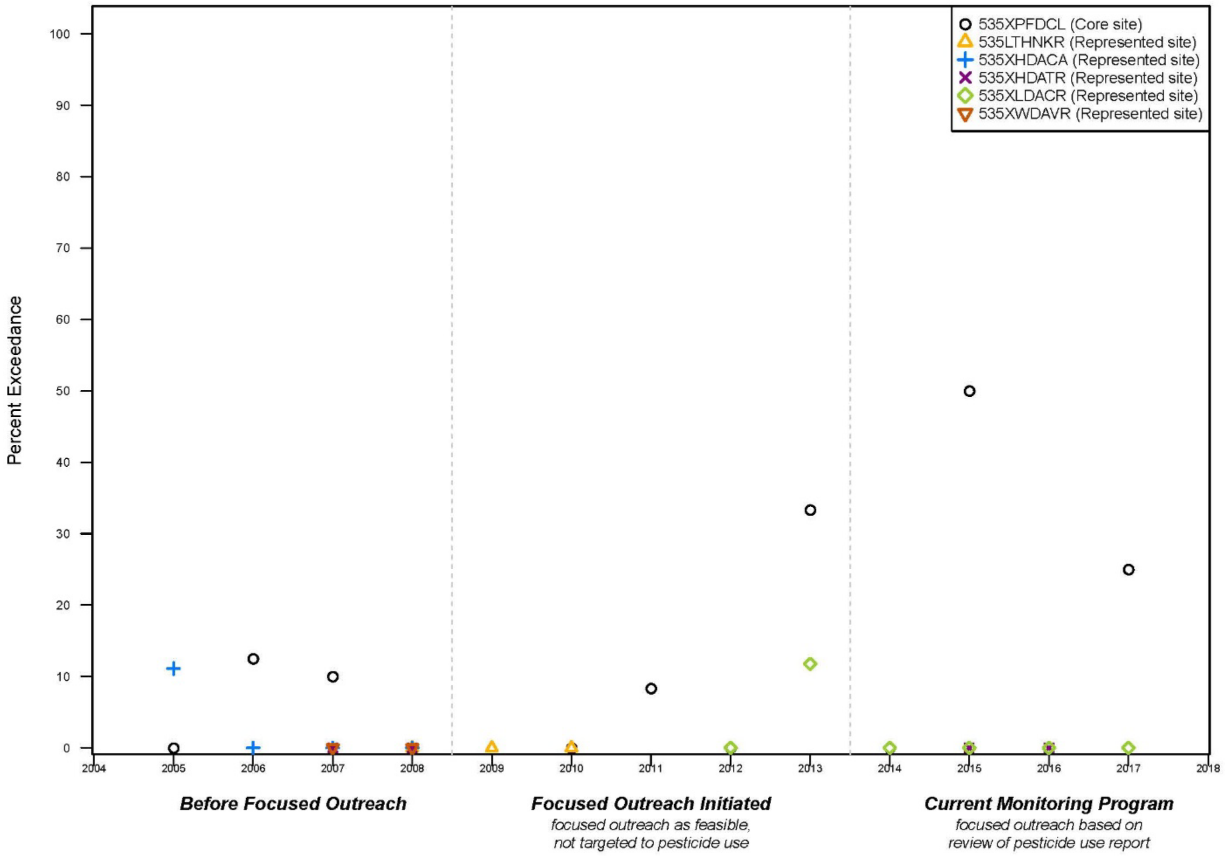

Figure 4-11. Annual exceedance rates for *Ceriodaphnia dubia* survival in Zone 2. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

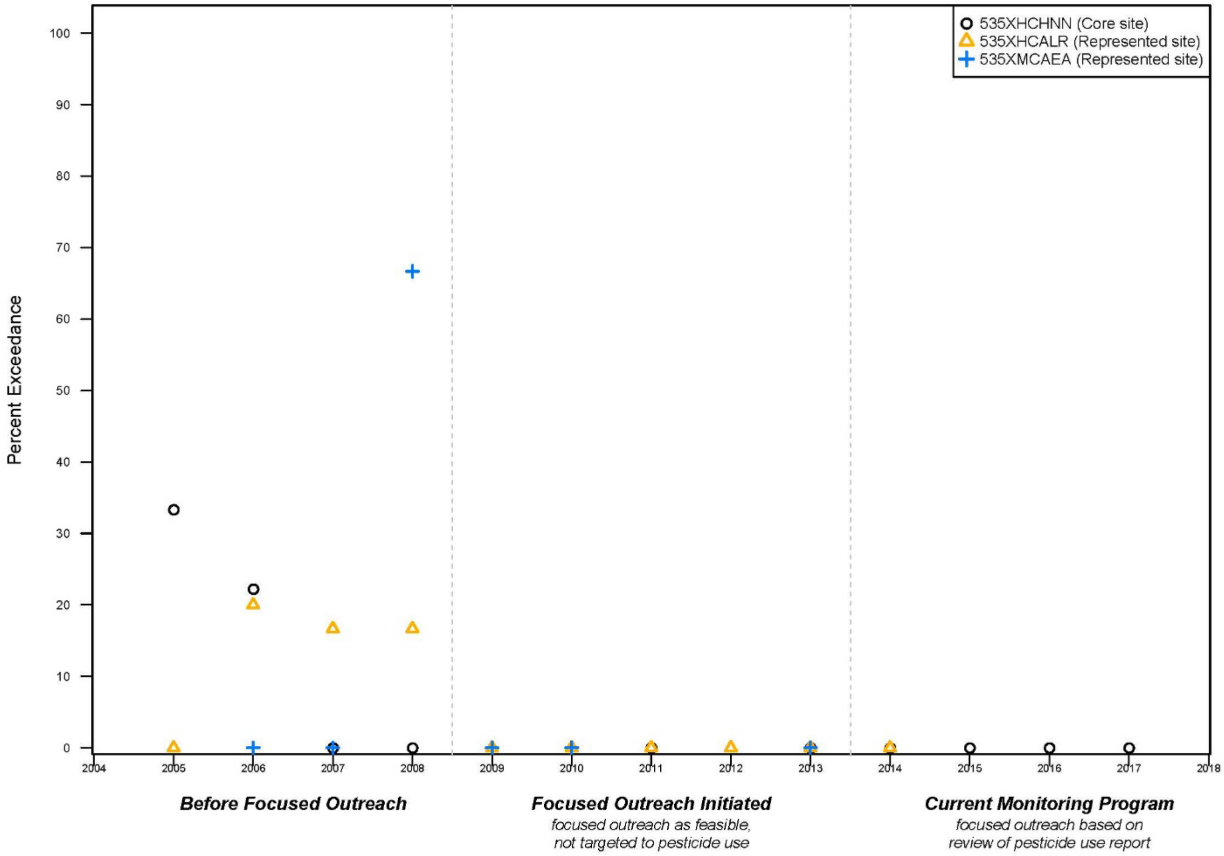

Figure 4-12. Annual exceedance rates for *Ceriodaphnia dubia* survival in Zone 3. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

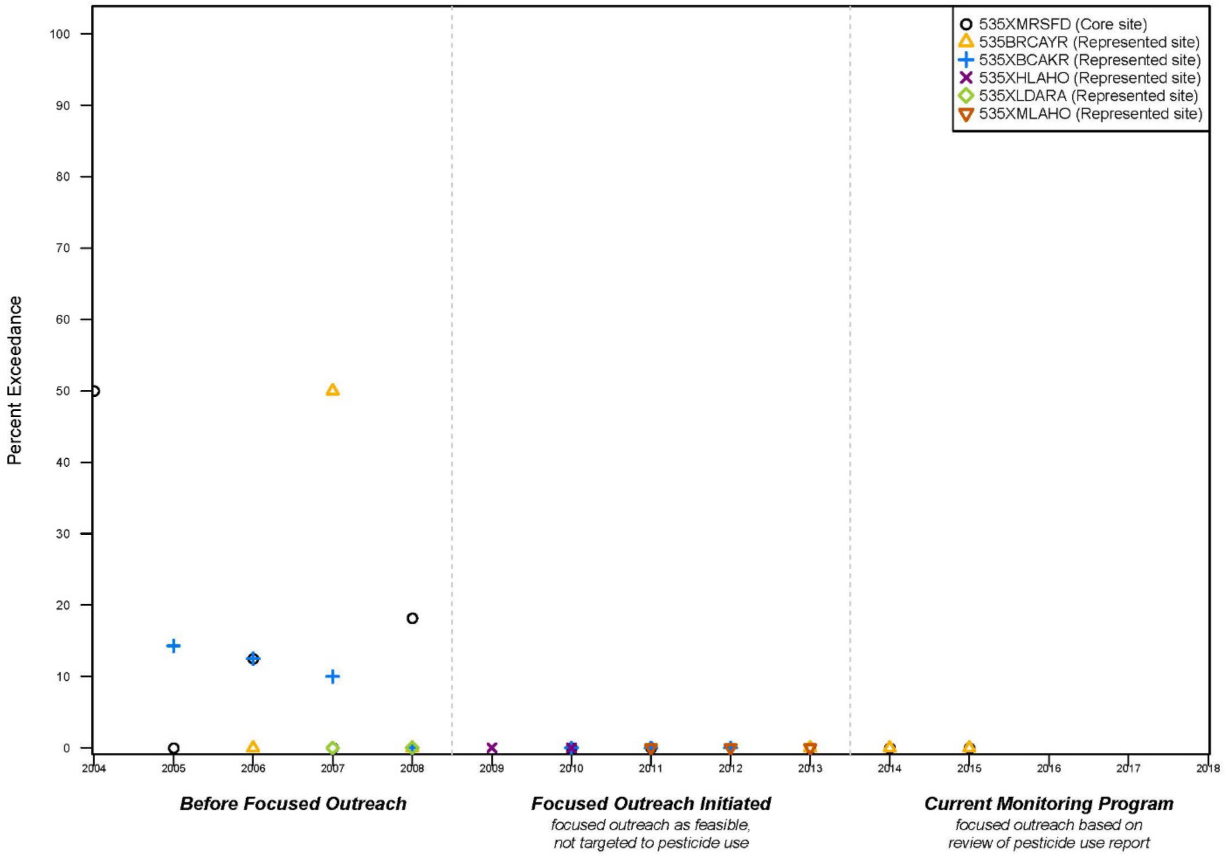

Figure 4-13. Annual exceedance rates for *Ceriodaphnia dubia* survival in Zone 4. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

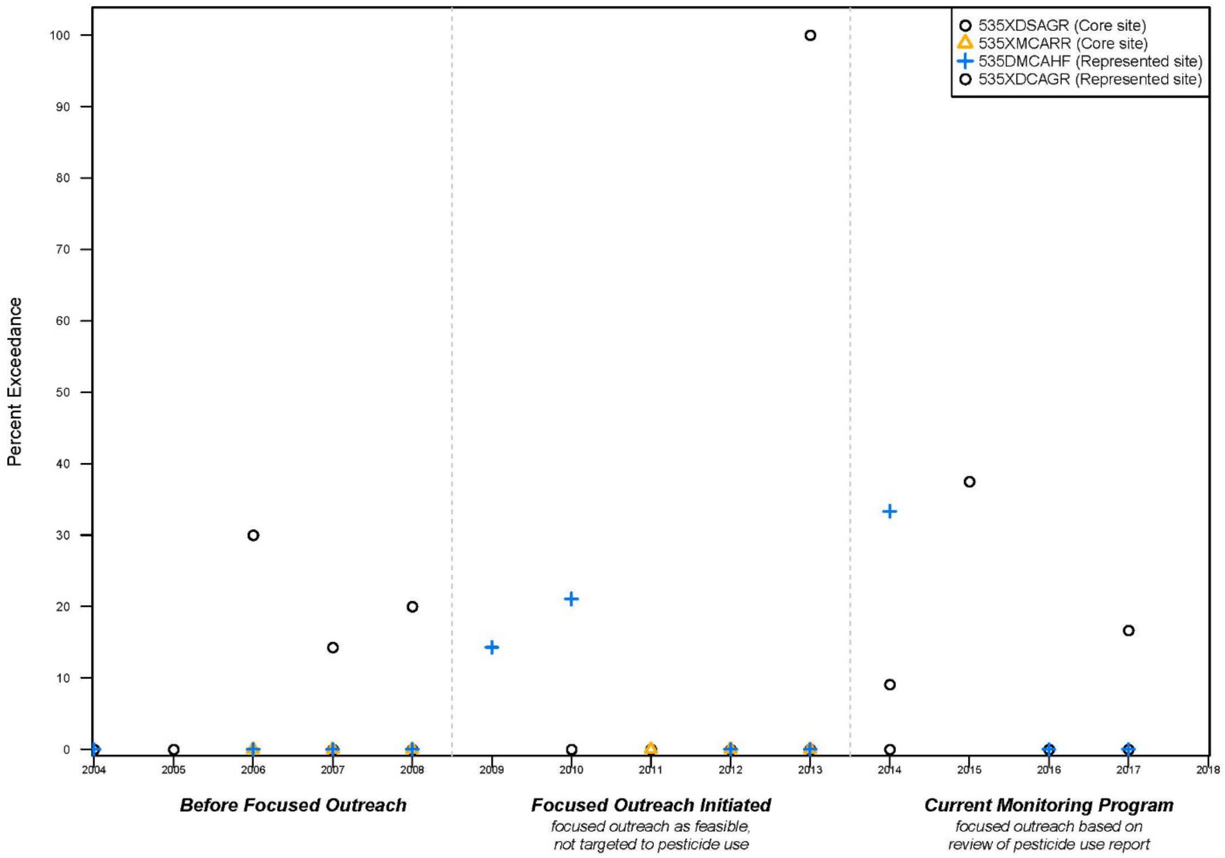

Figure 4-14. Annual exceedance rates for *Ceriodaphnia dubia* survival in Zone 5. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

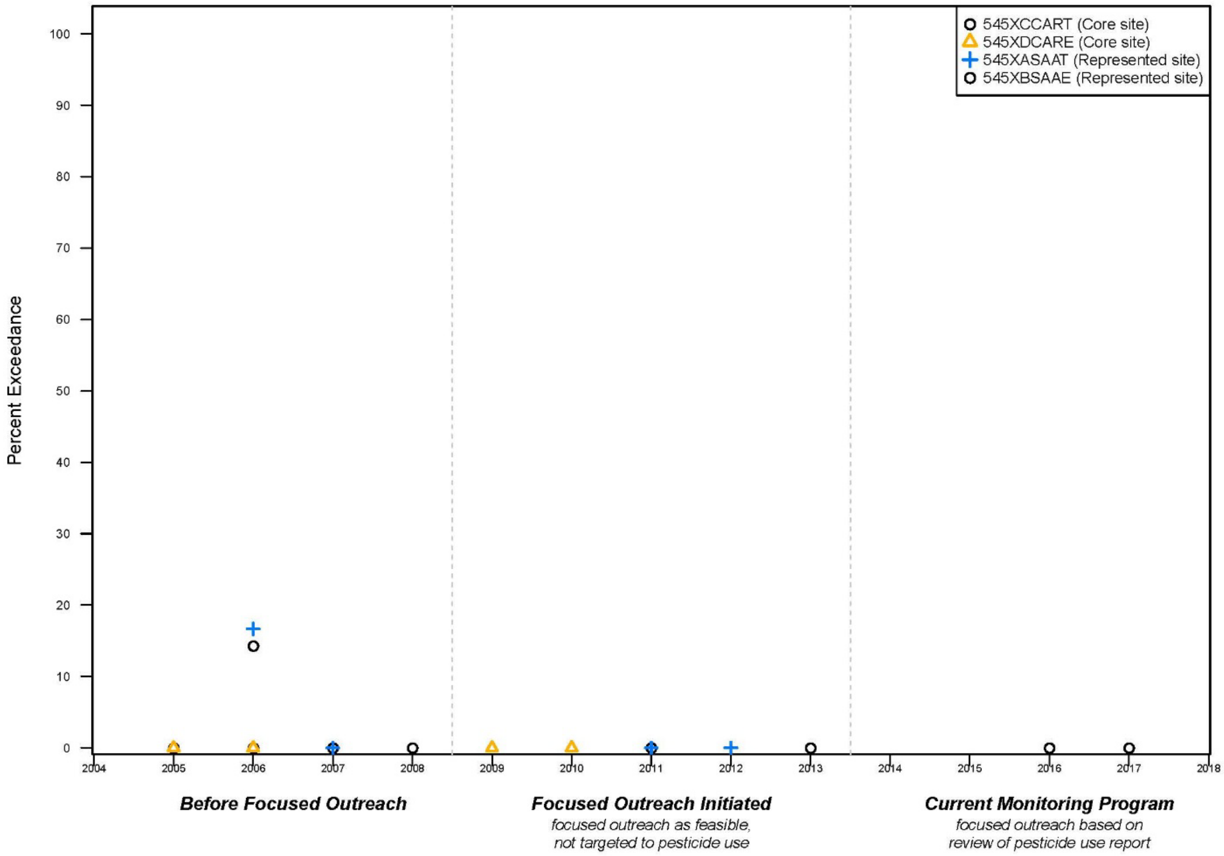

Figure 4-15. Annual exceedance rates for *Ceriodaphnia dubia* survival in Zone 6. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

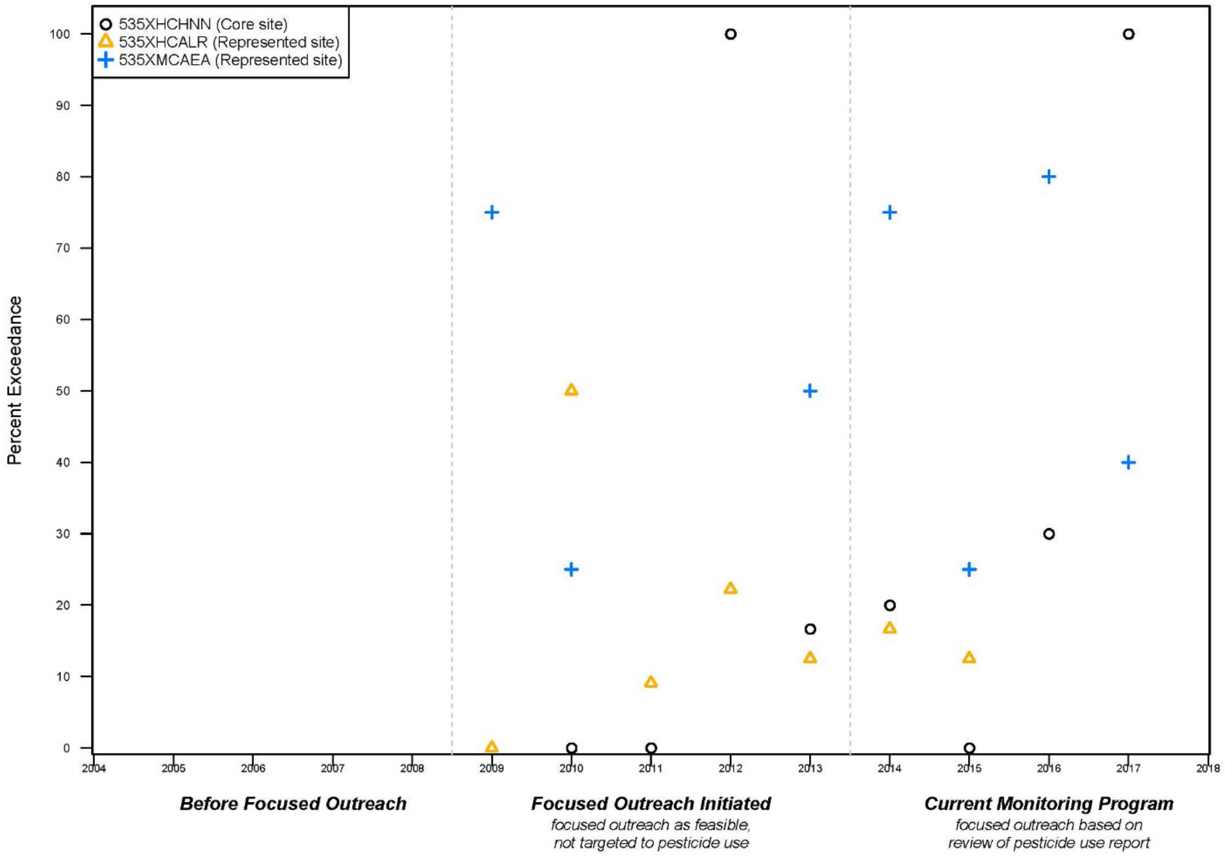

Figure 4-16. Annual exceedance rates for dissolved copper in Zone 3. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

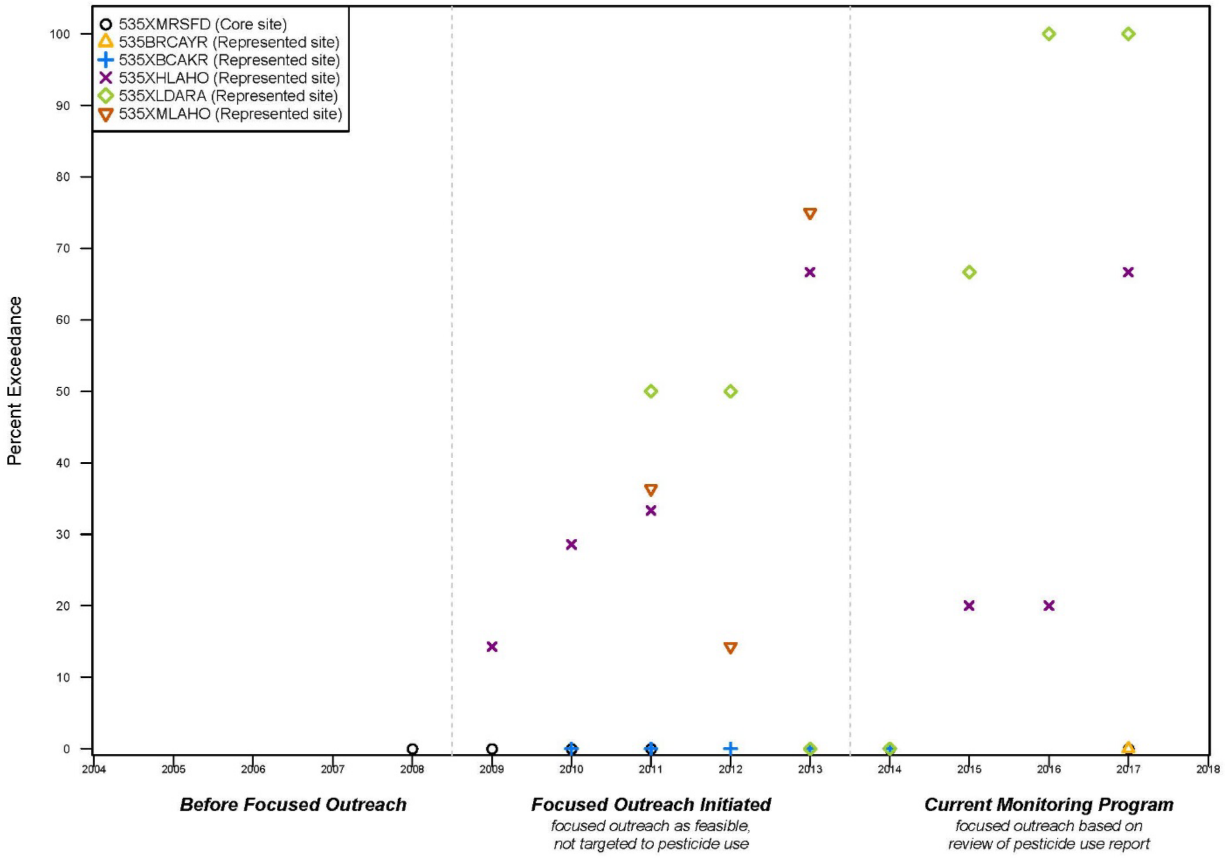

Figure 4-17. Annual exceedance rates for dissolved copper in Zone 4. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

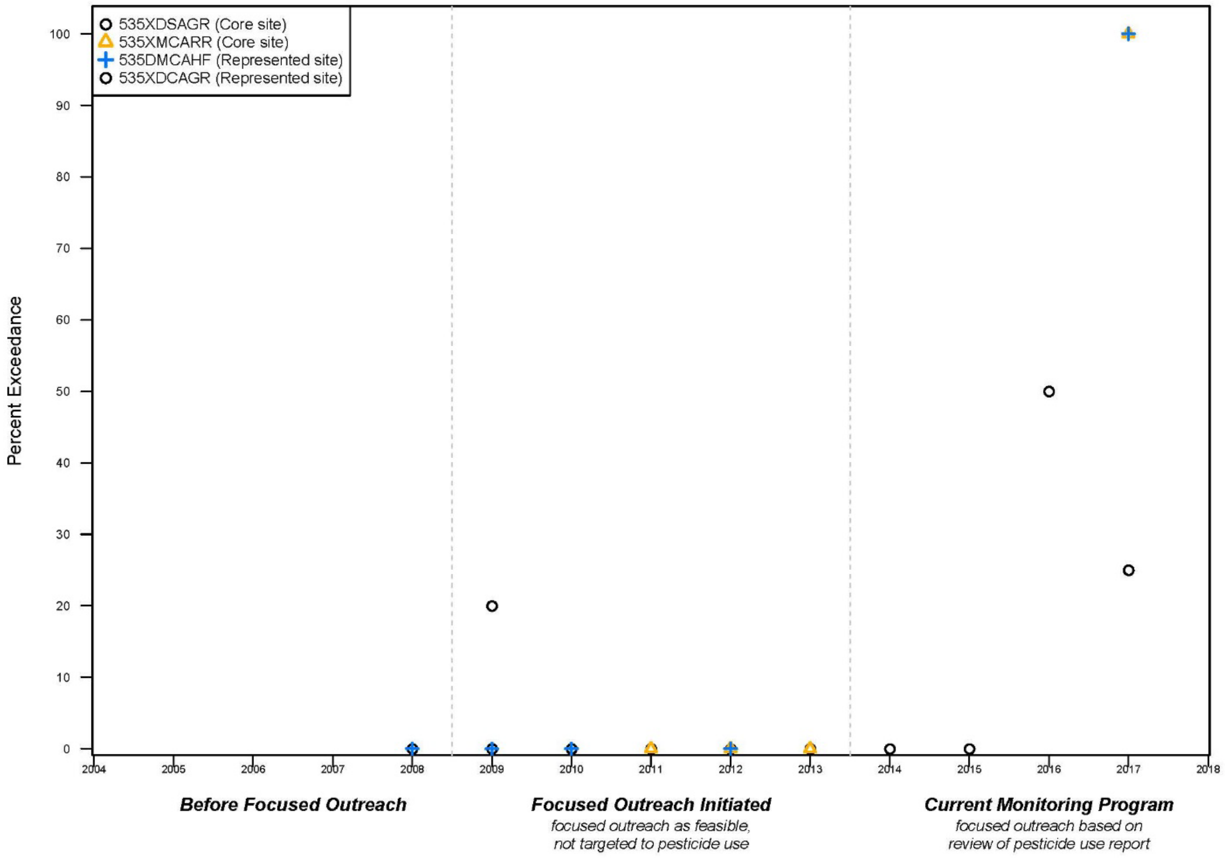

Figure 4-18. Annual exceedance rates for dissolved copper in Zone 5. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

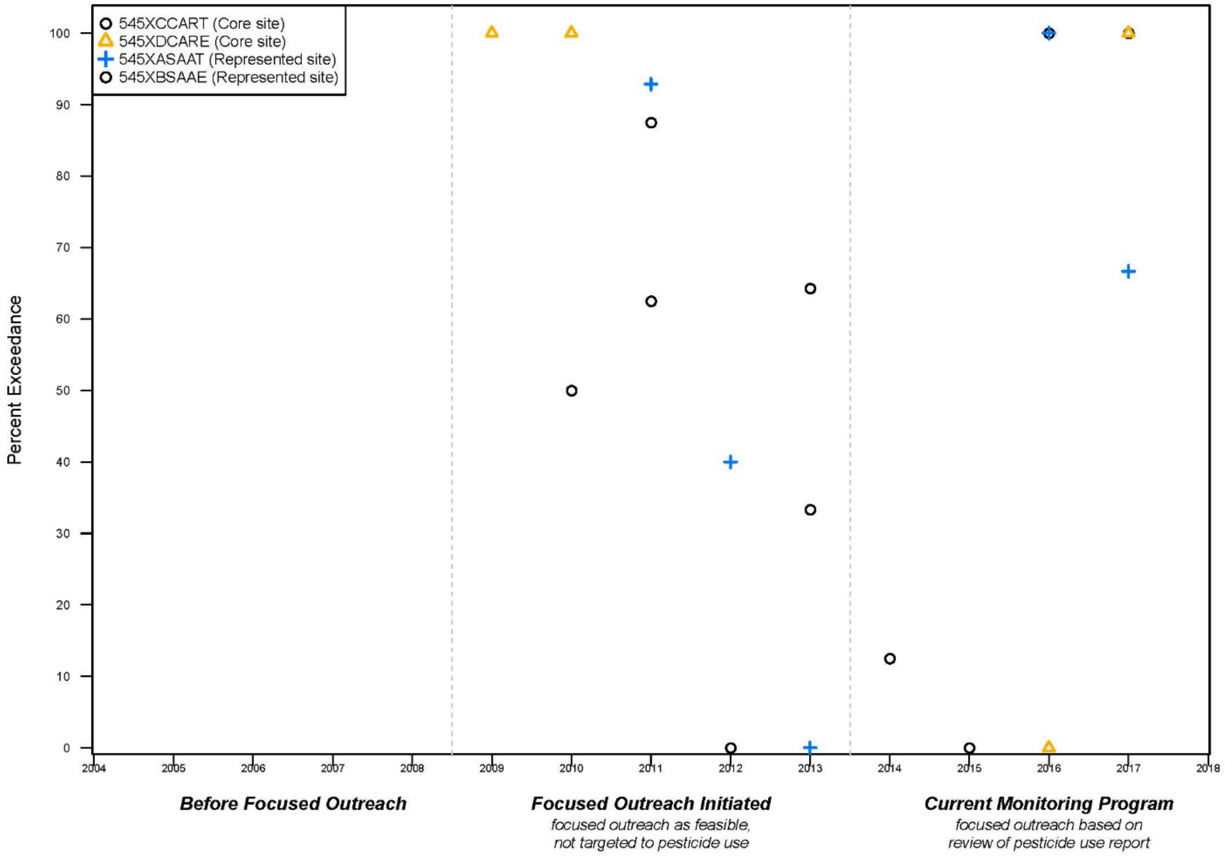

Figure 4-19. Annual exceedance rates for dissolved copper in Zone 6. Exceedance rates were calculated using data from sampling locations downstream of subwatersheds where outreach was conducted in two or more outreach periods.

4.4 Naturally occurring constituents and those with multiple potential sources show higher variability than constituents that originate primarily from agricultural sources, indicating that non-agricultural sources are likely important causes of exceedances.

To evaluate the importance of other sources to water quality concentrations at the monitoring points, Exponent evaluated the variability of measurements for individual constituents within each zone. In general, significant and persistent variability was common for metals and general water quality parameters, such as dissolved oxygen, pH, and *E. coli*. Data for many other constituents indicated many non-detect concentrations with occasional values above detection limits. (See Appendix D.) In general, constituent concentrations do not fit typical statistical distributions (e.g., normal, log-normal).

Variability was generally higher for metals and general water quality parameters, which have natural sources or multiple sources, than for constituents that originate primarily from irrigated lands. For example, Figure 4-20 shows all dissolved copper concentrations measured in samples collected from Core and Represented sites in Zone 1; the lack of filled circles or triangles indicates that no exceedances of hardness-dependent WQTLs for dissolved copper occurred. Although no samples exceeded WQTLs, dissolved copper concentrations in Zone 1 show substantial variability throughout the monitoring period, which may be related to rainfall and/or contributions from other sources, among other factors. Dissolved copper in Zone 6 (Figure 4-21) shows more variability in recent years than in the past; the reasons for this are unclear. Variability (i.e., the difference between low and high concentrations) in dissolved copper concentrations is up to 10 µg/L in each of the six zones; this level of variability has occurred during the entire monitoring program (2008–present).[33]

In contrast to results for dissolved copper, chlorpyrifos originates only from permitted agricultural uses, including irrigated lands both inside and outside the Coalition. Concentrations of chlorpyrifos exceeded the WQTL of 0.015 µg/L more often before 2009 than after 2009 in most zones; in addition, measured chlorpyrifos concentrations after 2009 are frequently below detection limits (Figures 4-22 and 4-23; see also Figure 4-4 though Figure 4-9). Exponent has been unable to correlate the decline in chlorpyrifos exceedances with environmental factors (such as rainfall), whereas the change in chlorpyrifos exceedances occurred after changes in the outreach program were implemented in 2008. The change in exceedance rates for chlorpyrifos indicates that it is likely that MPs implemented since 2009 have successfully eliminated or minimized chlorpyrifos exceedances in five of the six Coalition zones. Of note, Zone 2, which has the highest rate of exceedances, includes the largest number of agricultural operations that are non-members of the Coalition; thus, comparisons of data from Zone 2 with data from the

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[33] The Coalition monitored for total copper only from May 2006 to September 2008. Both total and dissolved copper were monitored from October 2008 to April 2014. From May 2014 to the present, only dissolved copper has been monitored.

other zones appear to indicate that outreach efforts and subsequent implementation measures are effective in reducing WQTL exceedances.

C. dubia survival[34] is somewhat variable but equal to or higher than 90% in water samples collected since about 2008 from Zones 1 and 6 (see Figures 4-24 and 4-25); prior to 2008, a few samples showed lower levels of survival. Results for Zones 3 and 4 are similar. Water samples collected from Zone 5 typically showed lower survival rates for *C. dubia* than other zones, even though chlorpyrifos levels were frequently below detection limits; in several samples that exhibited lower *C. dubia* survival rates, chlorpyrifos was not detected, indicating that lower survival rates in Zone 5 may be associated with other chemicals.

Overall, concentrations of constituents that arise naturally and from multiple sources, such as most metals, exhibit greater variability and fewer (or no) trends in observed concentrations over time, as compared to constituents originating solely or primarily from irrigated lands. For example, concentrations and variability have declined over time, particularly since 2009, for the pesticide chlorpyrifos. The decreases in chlorpyrifos concentration and variability correspond to the time period when intensive outreach and subsequent implementation of targeted MPs began to be implemented. Our analysis shows that monitoring program data appear to indicate that MPs implemented on irrigated lands are effective in reducing water quality problems for constituents that originate primarily from irrigated lands. Our analysis also indicates that implementation measures on irrigated lands are less effective in reducing ambient concentrations of constituents that originate from multiple sources or processes are less affected by MPs implemented on irrigated lands, which (by definition) do not address the multiple sources.

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[34] After adjusting for control survival.

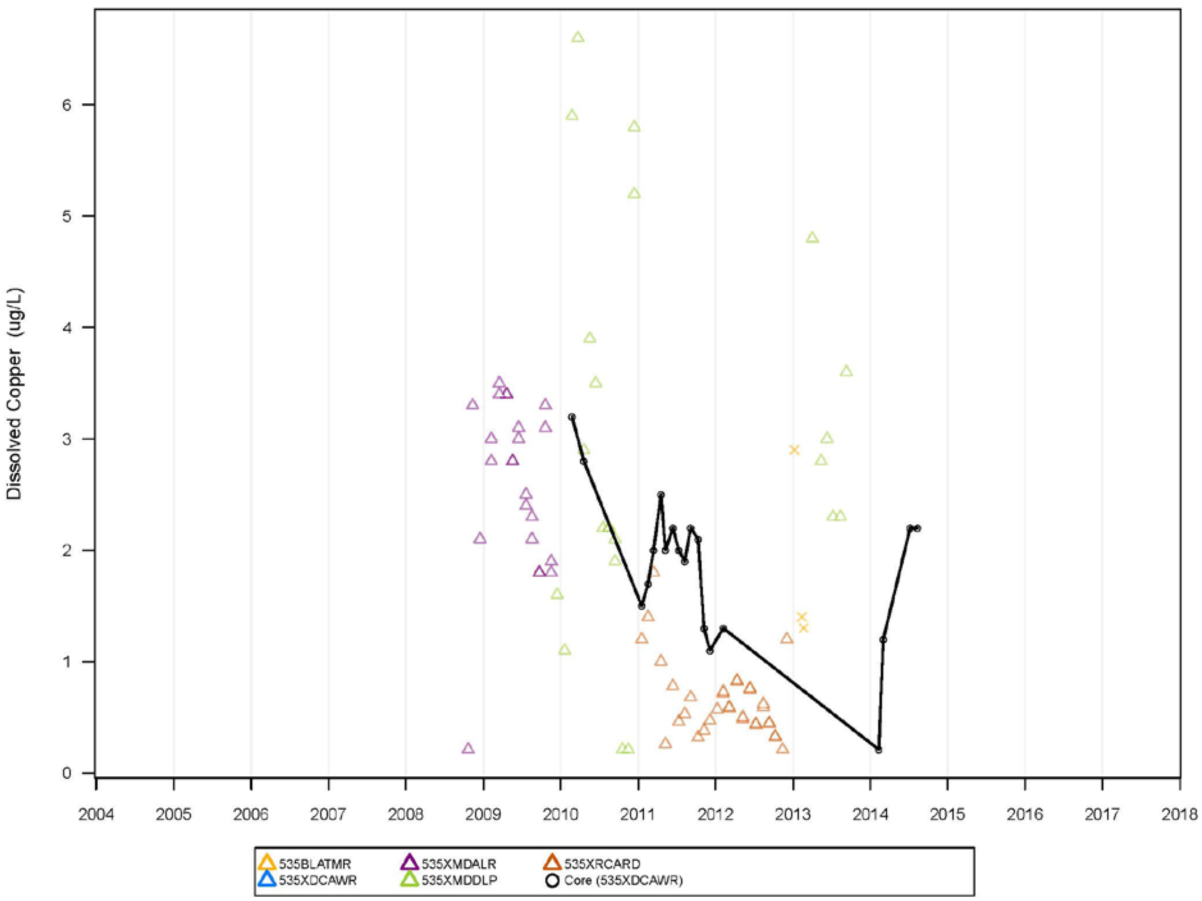

Figure 4-20. Dissolved copper concentrations measured in Zone 1. The solid line connects Core site monitoring results. Note that dissolved copper has not been measured at the Zone 1 Core site since August 12, 2014.

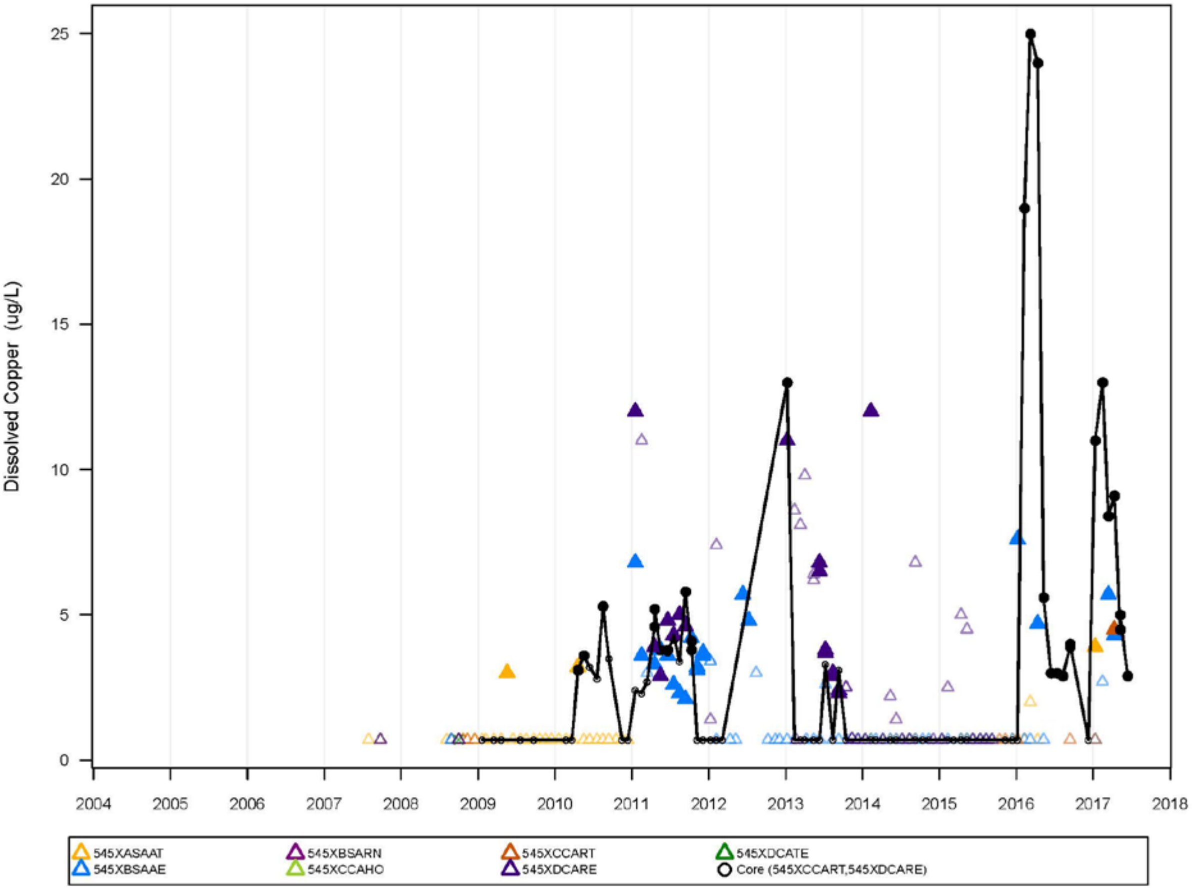

Figure 4-21. Dissolved copper concentrations measured in Zone 6. The solid line connects Core site monitoring results.

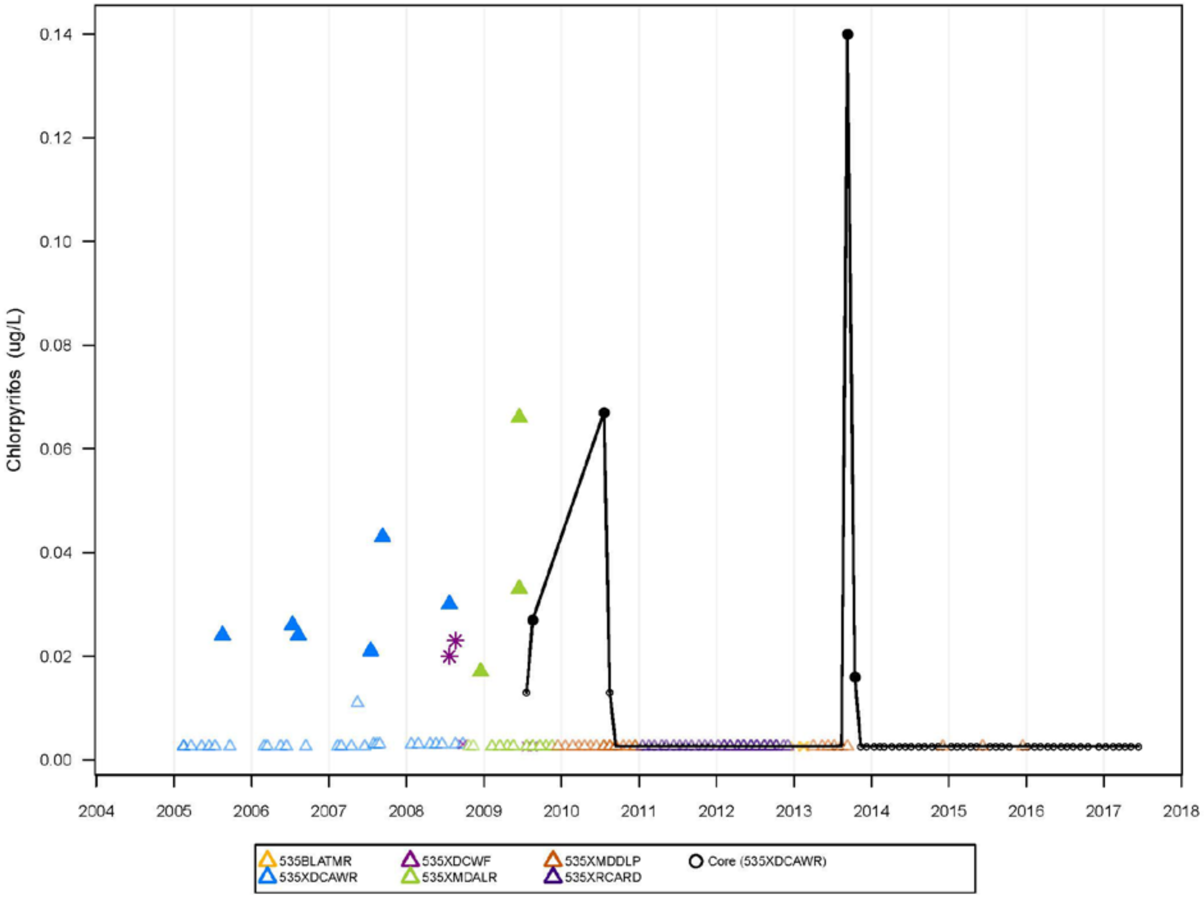

Figure 4-22. Chlorpyrifos concentrations measured in Zone 1. The solid line connects Core site monitoring results.

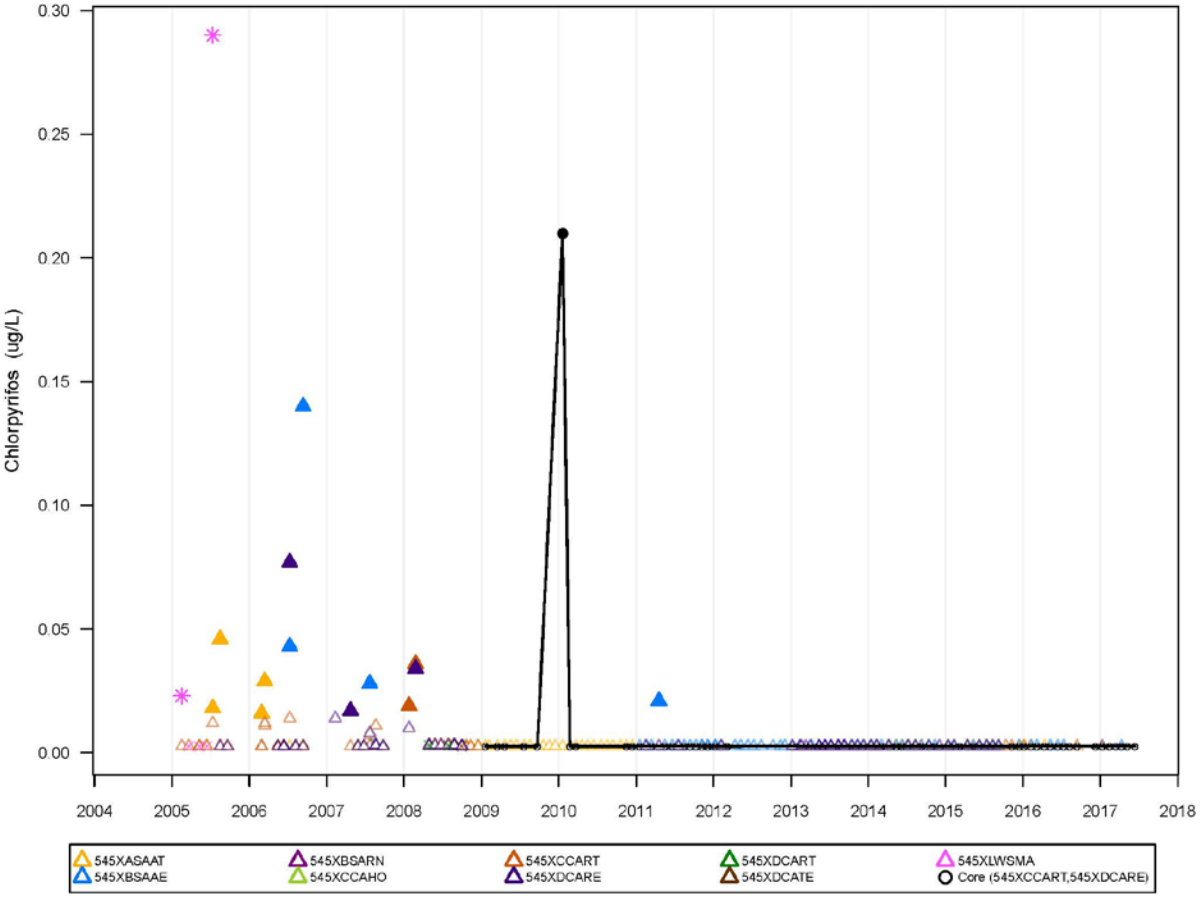

Figure 4-23. Chlorpyrifos concentrations measured in Zone 6. The solid line connects Core site monitoring results.

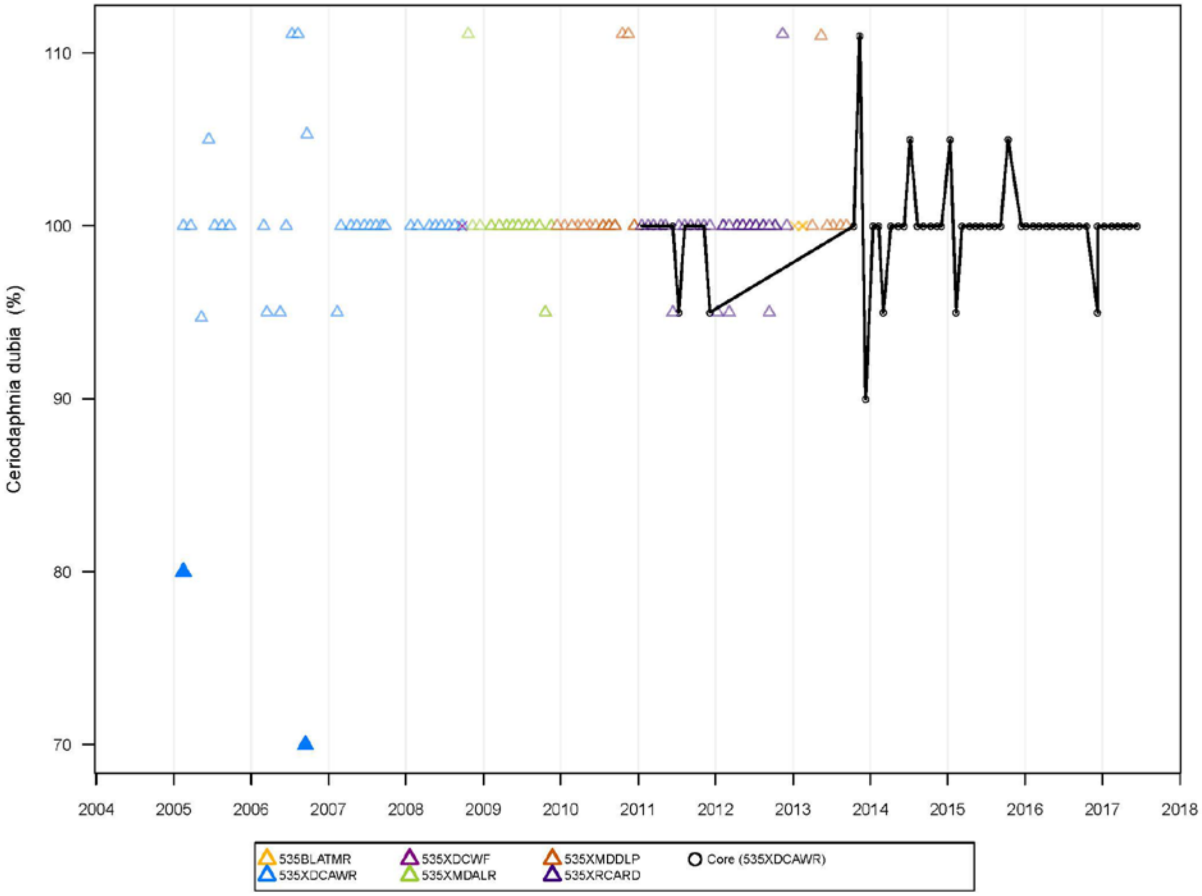

Figure 4-24. *Ceriodaphnia dubia* survival measured in Zone 1. The solid line connects Core site monitoring results.

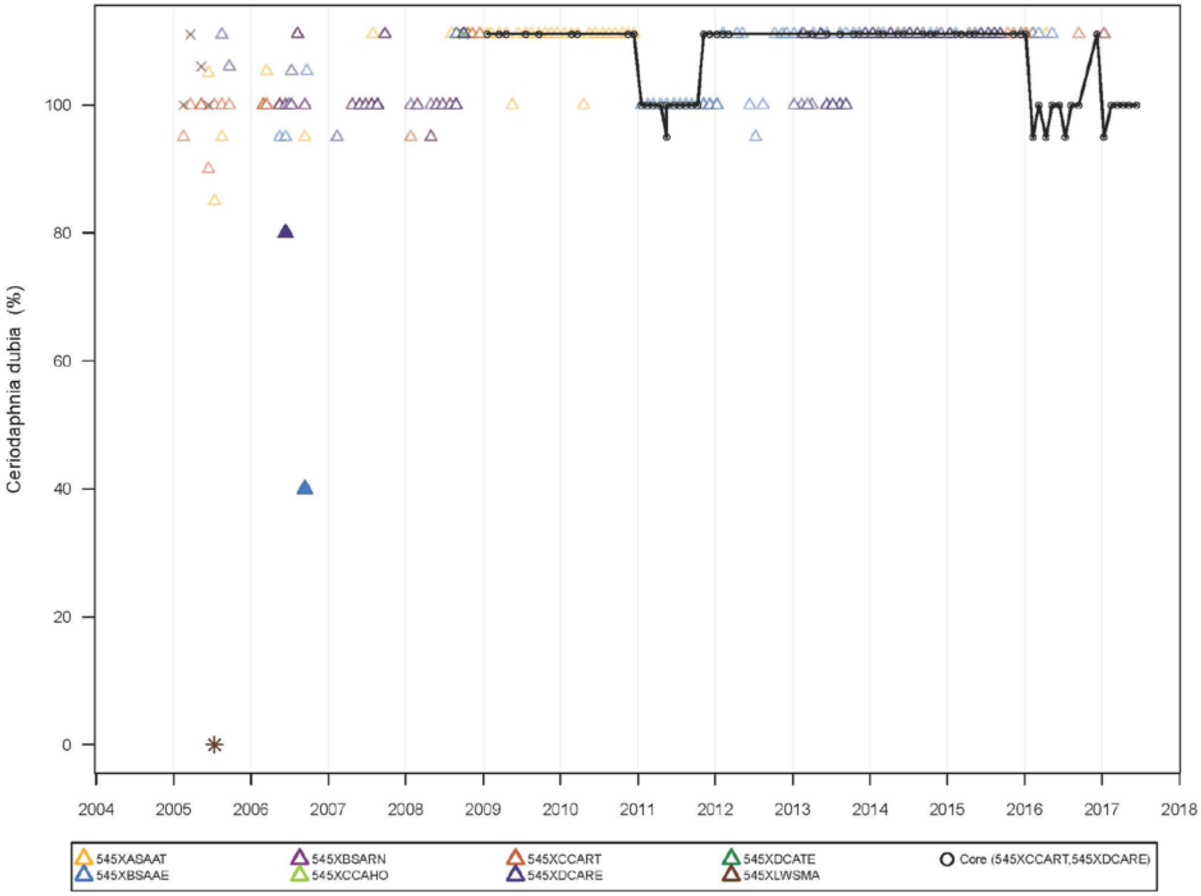

Figure 4-25. *Ceriodaphnia dubia* measured in Zone 6. The solid line connects Core site monitoring results.

4.5 The Coalition's monitoring program uses a structured framework to incorporate data on chemical use, risk, exposure, and fate in order to tailor monitoring and implementation measures and maximize the likelihood that water quality problems will be identified.

Beginning with the 2017 monitoring plan, the Coalition has formalized the process used to select chemicals for monitoring by implementing the Pesticide Evaluation Protocol developed using the PEP described in Section 3.2.3. The PEP identifies pesticides for monitoring based on chemical use by month within a zone, the potential for risk to aquatic life and human health, prior surface water monitoring data, and factors related to the chemical's behavior in the environment. The PEP is used to determine chemicals to be monitored and the months during which each chemical will be monitored at Core sites.[35]

To evaluate the representativeness of the zones and the PEP, which determines sampling plans for Core sites, Exponent applied the PEP to the Represented sites for two primary reasons: (1) to assess whether Protocol results are similar for Core and Represented sites as a means of assessing whether Core monitoring should be expected to yield results representative of the zone as a whole; and (2) to evaluate similarities and differences in chemical usage between Core and Represented sites.

As part of this analysis, Exponent evaluated the monthly AQL ratio, which is the ratio of the monthly 3-year average[36] volume of chemical applied in the area tributary to each Core site to the AQL reference value for each chemical (see Section 3.2.3). Higher AQL ratios indicate a high relative risk for a given chemical (i.e., a higher volume used and/or lower reference value), while lower AQL ratios indicate a lower relative risk. Figure 4-26 shows results of Exponent's comparison of the Core site and single Represented site in Zone 1; the data in Figure 4-26 represent average monthly pesticide use for 31 chemicals used at both sites. Figure 4-26 shows a high correlation (r = 0.79) between AQL ratios for Core and Represented sites, indicating

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[35] Pesticide usage and evaluation calculations provided to Exponent by MLJ-LLC.

[36] Ibid.

similarity in chemical use and risk between the sites. AQL ratios were also calculated for Core and Represented sites in each of the other five zones and, like results from Zone 1, show a similar high correlation of AQL ratios between Core and Represented sites (see Appendix E); correlations ranged from 0.79 to 0.99 for the 25 Represented sites in the six zones. The correlation analysis confirms the PEP would produce similar results (i.e., a similar list of chemicals to be monitored) at Core and Represented sites within each of the six zones. As noted in Section 4.2, the mix of crops planted upstream of Core and Represented sites within a single zone is also similar, again providing confirmation that Core and Represented sites are representative of conditions within each individual zone.

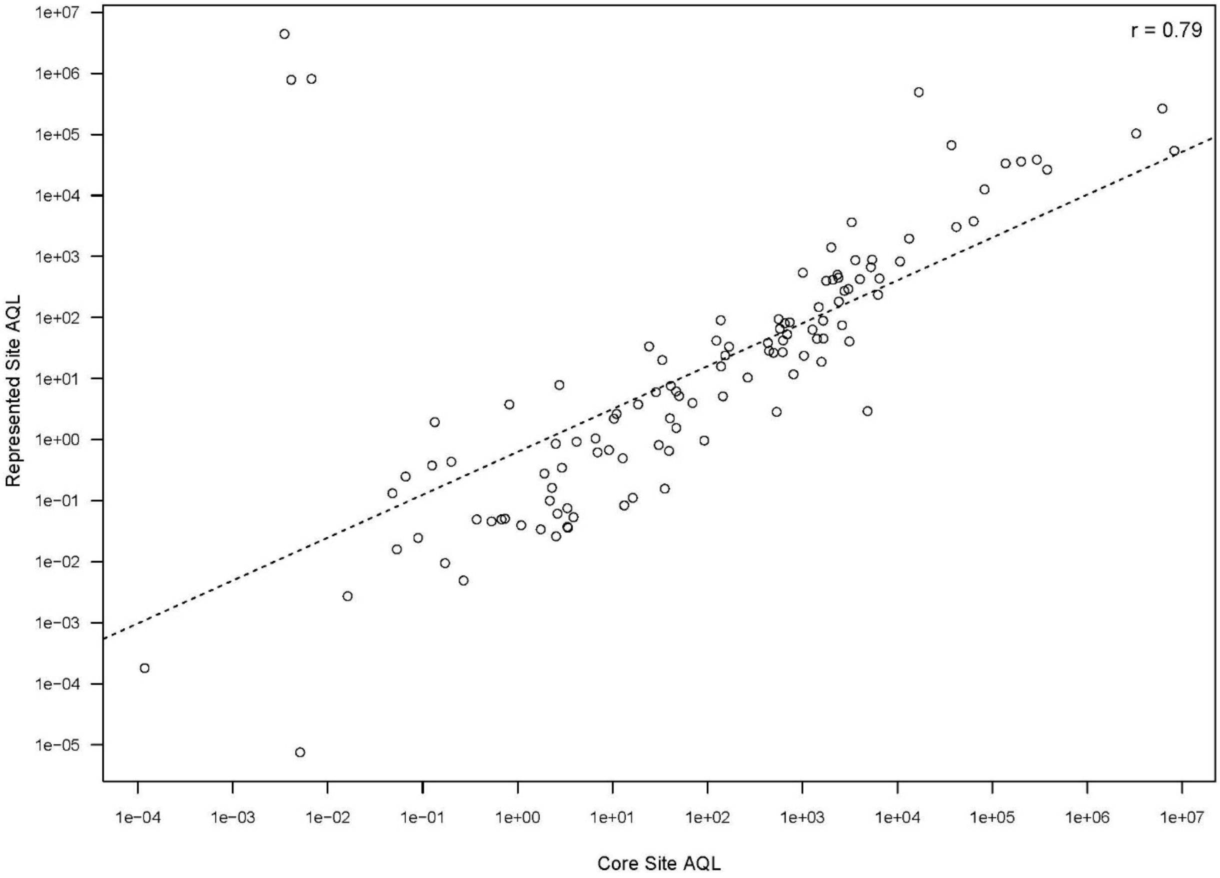

Figure 4-26. Correlation between aquatic life (AQL) ratios for the Core and Represented sites in Zone 1; data represent monthly 3-year average use for 51 chemicals. Axes are log-scale. High correlation (r) value is indicated on figure.

Although MLJ-LLC applies the PEP independently for each Core site, applying it for each Represented site provides a basis to compare recommendations across sites. For each site, each chemical, and each month, there are four potential outcomes from comparing the recommendation at a Represented site with the recommendation at the Core site: monitoring is recommended at (a) neither site, (b) both sites, (c) only the Core site, or (d) only the Represented site. This latter category reflects pesticides used within the subwatershed draining to a Represented site where the PEP did not result in a recommendation for monitoring for the Core site. If a chemical was not used for a site, it cannot be recommended for monitoring.

To evaluate consistency for site-chemical-month recommendations, Exponent summarized site comparisons of pesticide monitoring recommendations in Table 4-9. The columns labeled “Monitoring Aligned” in Table 4-9 show the number and percentage of monitoring recommendations (chemical-month combinations) for Core and Represented sites that were the same (i.e., categories (a) and (b)). The final set of columns in Table 4-9 (“Represented Sites Only”) shows the number and percentage of monitoring combinations where monitoring was recommended at the Represented site but not the Core site (i.e., category (d)). The center set of columns shows the same information for monitoring combinations where monitoring was recommended at the Core site but not at the Represented site (i.e., category (c)).

Table 4-9 indicates that the monthly pesticide monitoring recommendations were largely consistent for Core and Represented sites in all zones (65% or higher across all sites). In Zone 2, four of the nine Represented sites (535LFHASB, 535LSAFHR, 535LSSACA, and 535LTHNKR) were responsible for roughly 25% of monitoring recommendations applied to the Represented site only, and not to the Core site; Zone 2 has a larger fraction of agricultural operations that are not Coalition members and do not receive outreach from the Coalition because they are not subject to the irrigated lands WDRs and thus do not belong to the Coalition. These operations may account for these differences.

Exponent’s evaluations of the results of the PEP confirm that Core and Represented sites appear to be similar to each other within each individual zone, such that it is expected that both Core and Represented sites are generally representative of agricultural practices, pesticide use, and water quality within each zone as a whole.

Table 4-9. Consistency of Pesticide Evaluation Protocol monitoring recommendations between Represented and Core sites in each zone.

Represented Sites	Total Chemicals	Total Months	Monitoring Aligned Count	Monitoring Aligned Percent	Core Sites Only Count	Core Sites Only Percent	Represented Sites Only Count	Represented Sites Only Percent
Zone 1, Core site: 535XDCAWR								
535XMDDLP	51	340	95	74	19	15	14	11
Zone 2, Core site: 535XPFDCL								
535LFHASB	62	461	329	72	11	2	119	26
535LSAFHR	59	459	311	68	16	4	130	28
535LSSACA	62	483	351	73	13	3	117	24
535LTHNKR	63	533	377	71	15	3	139	26
535XHDACA	38	140	107	78	10	7	21	15
535XHDATR	30	94	71	77	7	8	14	15
535XLDACR	40	164	131	81	9	6	22	14
535XUDAHR	28	73	54	76	3	4	14	20
535XWDAVR	44	170	124	74	9	5	35	21
Zone 3, Core site: 535XHCHNN								
535XHCALR	55	414	302	82	7	2	60	16
535XMCAEA	44	257	156	74	14	7	42	20
Zone 4, Core site: 535XMRSFD								
535BRCAYR	47	156	91	71	16	12	22	17
535CCAWBR	53	256	176	78	17	7	33	14
535XBCAKR	53	295	194	72	20	7	54	20
535XHLAHO	56	333	245	81	30	10	29	10
535XLDARA	55	359	260	78	22	7	50	15
535XMLAHO	59	357	257	78	30	9	43	13
535XUDAHO	38	115	57	65	13	15	18	20
Zone 5, Core site: 535XDSAGR								
535DMCAHF	56	407	290	79	18	5	61	17
535XDCAGR	56	400	283	78	18	5	61	17
535XMCARR	58	360	265	82	27	8	30	9
Zone 6, Core site: 545XCCART								
545XASAAT	57	358	221	74	32	11	45	15
545XBSAAE	56	369	251	81	29	9	29	9
545XDCARE	52	334	217	74	31	11	26	9

Appendix A

Curricula vitae of Susan C. Paulsen, Ph.D., P.E. and Melanie Edwards

Appendix B

Crop Type Coverage Tables

Appendix C

Supplemental Figures: Percent exceedance relative to outreach

Appendix D

Supplemental Figures: Measured levels over time of constituents with one or more exceedances

Notes for All Figures

Filled symbols indicate exceedance of the WQTL

Results reported as undetected are included at the reported method detection limit

Empty symbols at default lowest values (for chemistry data and pH) or default highest values (for toxicity results) indicate that the site was visited for sampling but no sample was collected (e.g., due to the absence of water or unsafe conditions)

Appendix E

AQL Ratio Correlation Figures