Delta Regional Monitoring Program

FY18/19 Workplan and Budget

As approved by the Delta RMP Steering Committee on May 11, 2018

Amended on July 17, 2018

Updated on October 16, 2018

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Introduction

The purpose of this document is to provide the Delta RMP Steering Committee (SC) with a detailed workplan and budget for Fiscal Year 2018-2019 (FY18/19). The fiscal year covers the period from July 1, 2018 to June 30, 2019. This workplan covers the core functions of administration, finance, and governance. These annual tasks are planned to take place over the course of the fiscal year. In addition, the workplan describes monitoring projects for mercury, pesticides and aquatic toxicity, special studies for nutrients, and planning for future monitoring of contaminants of emerging concern (CECs). Monitoring projects authorized under this workplan have a project duration of 1.5 to 2 years and are planned to be completed by June 30, 2020.

For the upcoming fiscal year, the overall planned expense is **$1,053,888**. Forecast revenue from Delta RMP participants is **$1,180,256**, enough to cover all planned expenses and to create a surplus which can be allocated to additional tasks or transferred to the Undesignated Reserve Fund.

In addition, the workplan leverages **$$545,691** in in-kind contributions from other agencies, including the U.S. Geological Survey (USGS), U.S. Army Corps of Engineers, California Department of Water Resources (DWR), U.S. Bureau of Reclamation (USBR), Moss Landing Marine Laboratory (MLML), and the State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP). The planned studies also take advantage of and build off several projects funded by other agencies with a total value of $883,000.

Staff of the Aquatic Science Center (ASC) have worked with technical subcommittees to develop study proposals that are consistent with planning budgets set by the Steering Committee. The FY18/19 study proposals were vetted by the respective subcommittees and brought to the Technical Advisory Committee (TAC) on March 15, 2018. The subcommittees also worked to develop proposals that are consistent with feedback received by the 2016 External Review Panel.

In the spring of 2018, the TAC reviewed and prioritized the scientific studies based on the planning budgets for each focus area. Detailed workplans for these studies and proposed multi-year plans for the focus areas are provided as attachments to this workplan. ASC then prepared this detailed workplan for the recommended studies and core functions of the program. This document summarizes:

- Expected revenue for FY18/19;
- A detailed budget and workplan for the core functions of the program;
- A detailed budget and workplan for monitoring and special studies;
- The overall FY18/19 Delta RMP budget;
- The balance of Undesignated Funds Reserve.

This Detailed Workplan was approved by the Steering Committee on May 11, 2018, and added components covering pesticides, toxicity, and contaminants of emerging concern (CECs) at a subsequent meeting on July 17, 2018.

Revenue Forecast

In 2017, the SC elected not to increase fees for existing participants for FY18/19. Expected contributions from new and continuing participants amount to **$1,180,256**.

The Delta RMP has access to some in-kind funds that we can use at our discretion, such as a State Board contract with UC-Davis for toxicity testing (the "SWAMP Contract"). These funds are not "fungible." In other words, they cannot be used for any purpose other than toxicity testing, nor can they be used with a different vendor. Our budgeting and financial reporting for the Delta RMP only includes funds that we manage. However, we carefully track in-kind contributions to the program. See Table 8, **In-Kind Contributions** on page 23.

The number of Delta RMP participants has steadily grown over the life of the program, as shown below. Table 1 shows the how the number of Delta RMP participants has evolved, along with their financial contributions.

Table 1 History of Delta RMP participation and revenue

Fiscal Year	Number of Participants		Contributions by Participants	
FY 15/16	33		$751,733	
FY 16/17	35	+6%	$862,082	+15%
FY 17/18	49	+40%	$997,356	+16%
FY 18/19 (anticipated)	52	+6%	$1,180,256*	+18%

*This figure does not include a new $50,000 contribution by the Army Corps of Engineers that will be made directly to the USGS and will offset our monitoring expenses. This will be tracked as an in-kind contribution to the program.

Below, Table 2 summarizes the expected revenue for FY18/19 summarized by category of participant. Figure 1 shows revenue growth by participant category, showing actual revenue for the past three fiscal years and expected revenue for FY18/19.

Three new participants are expected to join the program in FY18/19:

(1) The California Department of Water Resources is expected to contribute $200,000. Their contribution is required under three separate permits issued by the Central Valley Regional Water Quality Control Board, covering projects related to dam operations and habitat restoration.

(2) The California Department of Transportation (CalTrans) stormwater management program is expected to contribute $80,000.

(3) The US Army Corps of Engineers, which dredges channels for navigation in the Delta, has been required to contribute $50,000 as a condition of their dredging permit issued by the Central Valley Water Resources Control Board. However, they will make their contribution to the program by directly funding the USGS. For administrative reasons, it is much easier for the Corps to transfer funds to another federal agency rather than paying a private contractor, which requires authorization by Congress. The Corps' contribution will offset program expenses for pesticides monitoring. Because this cash will never "hit our books," we are tracking this as an in-kind contribution. (In-kind contributions are listed in Table 8 on page 23.)

Table 2 Delta RMP Revenue Schedule

Participant	FY15/16 Actual	FY16/17 Actual	FY17/18 Actual	FY18/19 Forecast	Comment
Agriculture	$113,780	$148,780	$148,780	$148,780	
Dredgers	–	$60,000	$60,000	$63,000	Sacramento Yacht Club joining program in FY18/19; expected contribution $3,000.
Flood Control and Habitat Restoration	–	–	–	$200,000	**New category.** The California Department of Water Resources will join the program in FY18/19.
Stormwater (MS4 Phase 1)	$158,200	$158,200	$181,400	$261,400	CalTrans will join the program in FY18/19, contributing $80,000.
Stormwater (MS4 Phase 2)	$169,999	$189,999	$309,999	$309,999	12 new participants joined in FY17/18.
Wastewater	$209,754	$205,103	$197,077	$197,077	The City of Discovery Bay did not participate in the RMP in FY16/17, but did in FY17/18. By approval of the CV Water Board, the City of Stockton contributed $24,777 in FY16/17, but is permitted to pay $12,100 in other years.
Water supply	$100,000	$100,000	$100,000	–	SFCWA announced it is dissolving in 2018. To date, no other water supply agency has pledged to support the program.
Total	**$751,733**	**$862,082**	**$997,256**	**$1,180,256**	

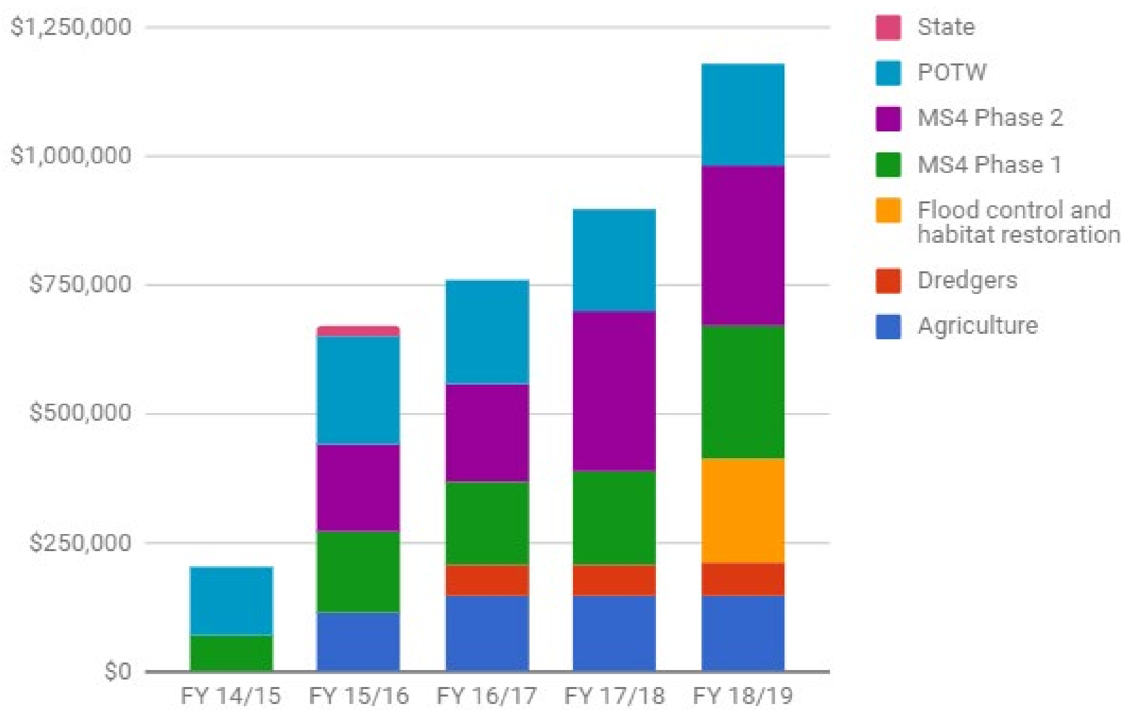


Figure 1 Bar chart of revenue by fiscal year and by participant category, showing actual revenue for the past 4 fiscal years and expected revenue for FY18/19.

Program Core Function Expenses

Delta RMP expenses fall into two categories: core function expenses associated with administering a multi-faceted, stakeholder-driven monitoring program; and special studies and monitoring to answer Delta RMP assessment questions. This section details the core function expenses for FY18/19. The core function budget includes the following categories of tasks:

- Preparation of program planning documents (e.g., Workplan, Monitoring Design)
- Contracts and financial management
- Governance
- Quality assurance

Table 3 shows how the planned core function budget for FY18/19 compares to last year's budget, both in terms of the number of hours of staff time and total expense. The planned budget for core functions is **$291,700**, somewhat smaller than the budgeted and projected expenses for core functions in FY17/18. Certain tasks have slightly higher budgets than last year, due to cost increases from inflation. However, the overall core functions budget is slightly lower as it does not contain certain items that were in the previous year's budget. Some of these tasks from the last fiscal year are unfinished. We anticipate rolling over any remaining funds following the close of the fiscal year and the reconciling of accounts. Below are notes on certain tasks:

- **Travel expenses** are no longer included under any task. Due to a change in SFEI-ASC's policies and accounting practices, travel expenses are not charged to the Delta RMP when employees use a company vehicle.
- **Task 2A, Steering Committee Meetings ($38,400)**. This budget line is lower this year as we have decided that the SC co-chairs will run meetings and we can do without the services of a paid facilitator, resulting in a savings of over $10,000.
- **Task 2C, Technical Subcommittees ($37,000).** This task is intended to cover ASC staff time to organize and participate in technical subcommittee meetings. This is an important part of program planning and monitoring design, and a key part of our strategy to respond to the critiques of the 2016 External Review Panel. This task was *increased* by $17,000 compared to last year as we have added 2 new subcommittees covering Contaminants of Emerging Concern (CECs) and Data Management. In addition, the costs for running the Nutrients Subcommittee were *not* part of this budget in FY17/18[1] but will be for FY18/19. Organizing and preparing for these committee meetings is critical for the success of the program. The meetings are where scientific work products are reviewed, new study ideas are developed, and coordination with other stakeholders occurs. Staff time is needed for the following tasks: preparing agendas, agenda materials and presentations; participating

[1] These costs were charged to a separate budget line (FY17/18 Task 9B).

in meetings; writing meeting summaries; following up on action items; and discussions with participants and stakeholders outside of meetings.

There are a number of tasks which we did **not** include in the FY18/19 budget because either there will be carry-over funds from the FY17/18 budget or no activity is planned for this year.

- **FY17/18 Task 2E, Science Advisors ($10,000)** will pay the honoraria and travel for 2 to 4 independent science advisors. The advisors would be selected by the Steering Committee with input from the TAC and would commit to a 3 to 4 year term. These funds went unspent in the previous fiscal year due to the long process of nominating and selecting advisors, and we shall carry over these funds over for use in FY18/19.
- **FY17/18 Task 4B Draft the Pulse of the Delta ($40,000)** was meant to begin drafting the *Pulse of the Delta* report. In the Communications Plan, the *Pulse of the Delta* is described as the flagship publication of the Delta RMP. ASC did not spend much time on this task in FY17/18 because the Steering Committee did not have the opportunity to provide direction on this important document. Therefore, most of the allocated funds are unspent. A *Pulse* document typically requires having 3-4 technical reports completed and approved by the Steering Committee a 9-12 months in advance, after which the Steering Committee works on high-level messaging. A number of technical reports will be completed by the end of FY18/19, most significantly an interpretive report of the Delta RMP pesticide and toxicity data. Therefore, ASC recommends carrying over the unspent funds to do planning in FY18/19 and producing the report in 2020.
- **Factsheets and Outreach Products** – not essential as we have created a new factsheet in FY17/18 that should serve the program for at least a year.
- **Workshops and Technical Meetings** – While there are no workshops planned at the moment, the Steering Committee may wish to revisit this following the scoping of work related to Contaminants of Emerging Concern (CECs) or as other needs arise.

Full details about the labor, subcontract, and direct costs as well as the deliverables to be accomplished for each of the core functions tasks are provided in Table 4.

Table 3 Delta RMP FY18/19 core function budget with comparison to previous fiscal year.

	FY17/18 Projected Staff Hours*	FY18/19 Budgeted Staff Hours*	FY17/18 Budgeted Expenses	FY17/18 Projected Expenses*	FY18/19 Budgeted Expenses
1. Program Management					
A. Program Planning	438	420	$65,000	$64,980	$68,250
B. Contract and Financial Management	509	480	$54,000	$53,870	$56,150
			$138,000	**$118,850**	**$124,400**
2. Governance					
A. SC meetings	284	320	$48,484	$46,379	$38,400
B. TAC meetings	293	320	$61,620	$58,220	$59,400
C. Technical Subcommittees	163	260	$20,000	$19,888	$37,000
D. Science Advisors	-	-	$10,000	$10,000	-
			$140,104	**$134,487**	**$134,800**
3. Quality Assurance					
A. Quality Assurance System	90	128	$15,000	$17,250	$17,500
B. Technical Oversight and Coordination	110	80	$15,000	$13,392	$15,000
C. Data Management Subcommittee	44	-	$5,000		
			$30,000	**$30,642**	**$32,500**
4. Communications					
A. Stakeholder Board Meetings	40	-**	$10,000	$10,000	–**
B. Delta RMP Update Draft	175	-**	$40,000	$40,000	–**
C. Data Assessment Framework Workshop	43	-**	$5,000	$5,000	–**
			$55,000	**$55,000**	**$0**
Total	**2,189**	**1,948**	**$363,104**	$338,979	**$291,700**

*FY17/18 projected staff hours and expense includes hours billed to date plus our best estimate of the number of hours to complete tasks.

**Most of the planned hours for these tasks were not spent in FY17/18. Anticipated to be rolled over and spent in FY18/19 according to project needs.

Table 4 Delta RMP FY18/19 Programmatic Task Descriptions, Budget Justifications, and Deliverables.

Task	Subtask	Budget	Description	Budget Justification	Deliverables
01. Core Functions	A. Program Planning	$68,250	Planning, preparing annual workplans and budgets, including technical proposals for monitoring and special studies. Tracking deliverables and action items. Updating foundational documents including Charter, Multi-Year Plan, Communications Plan, and Monitoring Design as needed.	40 hours for Program Manager to produce the Annual Workplan and Budget. 100 hours (2 hrs/wk) for Program Manager to track and execute deliverables/ action items. 280 hours (5.6 hr/wk) for technical staff to develop study designs and monitoring designs, contribute to workplan, complete project management tasks, and update program documents. (420 hours total.) Includes a $3,120 subcontract with Applied Marine Sciences (AMS) for statistical consulting and monitoring design.	FY19/20 Annual Workplan and Budget (May 2019). Technical study proposals for the technical subcom-mittees. Quarterly reports on deliverables and action items provided in the SC agenda package. Updates to foun-dational documents such as Charter, Monitoring Design, and Communications Plan as necessary.
	B. Contract and Financial Management	$56,150	Tracking expenditures versus budget. Providing quarterly financial updates to the Steering Committee. Developing contracts and managing subcontractors. Invoicing program participants.	240 hours for Contracts Manager/Finance Associate and 60 hours for accountant (1.5 hr/$5000 budget). 40 hours for Program Manager and 40 hours for technical staff to draft and negotiate contracts and compile legal advice. 50 hours for Program Manager (1 hr/wk) and 50 hours (1 hr/wk) for Environ-mental Analyst for monitoring program subcontracts and finances weekly. (480 hours total). $500 for shipping, postage, office supplies.	Quarterly updates on budget and expenses provided in the SC agenda package. Contract management.
02. Governance	A. SC meetings	$38,400	Preparing agendas, agenda packages, participating in meetings, editing meeting summaries, following up on action items, meeting with Co-Chairs and stakeholders outside of meetings.	4-5 meetings per year. For each meeting: 40 hours for Program Manager, 20 hours for Lead Scientists, 20 hours for Environ-mental Analyst. Facilitation by the co-chairs at no additional cost to the program. $2,400 for note taking and meeting summaries by Daphne Orzalli.	4 Steering Committee meetings and meeting summaries, and 1 shorter (1-3 hour) phone meeting

Task	Subtask	Budget	Description	Budget Justification	Deliverables
02. Governance (continued)	B. TAC meetings	$59,400	Preparing agendas, agenda packages, participating in meetings, writing meeting summaries, following up on action items, meeting with Co-Chairs and stakeholders outside of meetings. The cost for this function assumes that MEI and USGS continue to serve as co-chairs of the TAC, with ASC serving in a coordination role.	4-5 meetings per year. For each meeting: 20 hours for Program Manager, 40 hours for Lead Staff, 20 hours for Environmental Analyst. TAC Chairperson services provided by MEI (quote: $19,200) and USGS. Total of 80 hours for Stephen McCord: Facilitation of 4 TAC meetings (24 hrs), participate in SC meetings (16 hrs), review documents and coordinate with Delta RMP participants and leadership (40 hrs). $2,400 for taking and meeting summaries by Daphne Orzalli.	4 Technical Advisory Committee meetings and meeting summaries, and 1 shorter (1-3 hour) phone meeting
	C. Technical Subcommittees	$37,000	Preparing agendas, agenda materials and presentations, participating in meetings, writing meeting summaries, following up on action items, discussion with participants and stakeholders outside of meetings.	16 meetings per year. For each meeting: 4 hours for Program Manager, 12 hours for Lead Staff, 4 hours for Environmental Analyst. Increased over FY17/18 as we have added 2 new subcommittees covering CECs and Data Management. (256 hours total)	Agendas and informal summaries for up to 16 subcommittee meetings.
03. Quality Assurance	A. Quality Assurance	$17,500	Updating the Quality Assurance Project Plan, writing Quality Assurance Reports for datasets, coordinating interlaboratory comparison tests (as needed), researching analytical methods, maintaining laboratory SOP file system.	40 hours for ASC QA Officer. 16 hours for ASC senior chemist, 16 hours for chief data scientist, 16 hours for GIS specialist, 40 hours for RMP technical staff. (128 hours total)	Revisions to QAPP (Fall 2018 and Spring 2019).
	B. Technical Oversight and Coordination	$15,000	Covers a variety of issues related to running a multi-faceted monitoring program. Coordination with subcontractors and field crews, reviewing reports, troubleshooting.	64 hours for technical staff (16 hours per quarter). 16 hours for ASC Senior Scientists (4 hours per quarter). (80 hours total)	

Expenses for Monitoring and Special Studies

This workplan contains monitoring and special studies for mercury, nutrients, pesticides and aquatic toxicity, and a planning budget to lay the groundwork for future monitoring of contaminants of emerging concern (CECs). The process for developing these studies and TAC comments on the proposed work is described in a memo to the Steering Committee dated May 2, 2018. No further studies are planned for pathogens at this time.

The total cost for the monitoring programs and special studies amounts to **$762,188**. Planned expenses are detailed in Table 5 on page 18. At the October 2017 Joint SC and TAC meeting, the subcommittees were charged with developing proposals with approximate budgets of $250,000 for each focus area. Therefore, the proposals developed by the subcommittees were close to the planning budgets set by the SC. Note that the SC elected to fund the Chlorophyll Intercalibration study (Task 4B) at only 50%, and has requested additional funding for this task from the Bay Nutrient Management Strategy (NMS). Available funding covers the startup phase only. In the summer of 2018, the NMS Steering Committee voted to approve funding covering the remainder of the study.

The budgeted cost of each of the planned monitoring programs is shown in Table 5. Further details of the budget by task for monitoring and special studies are shown in Table 6. The tasks to be completed, subcontractors, and deliverables for these tasks are described briefly below and in detailed monitoring designs attached as appendices to this document:

Appendix A: Nutrients
Appendix B: Mercury
Appendix C: Pesticides
Appendix D: Contaminants of Emerging Concern

Mercury - $277,210

Mercury monitoring in FY18/19 will collect samples of sport fish and water in order to address the highest priority information needs related to implementation of the Methylmercury TMDL. The program extends upon FY17/18 by continuing annual sport fish sampling at 7 sites and expanding water sampling to 8 times per year at the same 8 sites that were monitored in FY17/18. Sediment monitoring is not planned in FY18/19. Monitoring will provide essential evidence for regulators implementing the TMDL and contribute to ongoing analytical work by the California Department of Water Resources (DWR), and which will be used to guide regulations and operational decisions related to farming, flood control, and wetland management.

As shown in Table 5 below, the scope and budget for mercury monitoring has grown steadily, as the program seeks to provide timely information to the Central Valley Regional Water

Quality Control Board as it is updating the Delta Methylmercury TMDL. It is anticipated that after FY19/20, mercury sampling budgets can be trimmed down to a lower level while continuing to conduct baseline monitoring in order to build up a long-term time series that will be useful to managers in the long run.

Table 5. Sampling frequency for the first two years of Delta RMP mercury monitoring, and planned and desired frequency in the next two years.

	Fish			Water			Sediment		
	Events	Sites	# Samples	Events	Sites	# Samples	Events	Sites	# Samples
FY16/17	1	6	6	4	5	20	-	-	-
FY17/18	1	6	6	7	6 - 8	54	4	6	24
FY18/19	1	7	7	8	8	64	-	-	-
FY19/20	1	7	7	10	8	80	-	-	-

Nutrients - $228,400

Two special studies are planned for FY18/19. The two projects are:

- Merging High-Frequency Water Quality Data and Models to Gain Insights into the Factors Regulating Phytoplankton Blooms in the Delta in WY2016
- Intercalibration Study for Chlorophyll Fluorescence Sensors in the Bay-Delta, Phase II

Short summaries of these special studies are listed below. The full monitoring designs are included in Attachments to this workplan.

Merging High-Frequency Water Quality Data and Models to Gain Insights into the Factors Regulating Phytoplankton Blooms in the Delta in WY2016 - **$186,000**

For this study, we plan to combine a hydrodynamic-biogeochemical model of the Delta in WY2016 with water quality measurements in order to understand what caused large phytoplankton blooms in this year. The approach will be to apply a biogeochemical model developed for WY2011 to WY2016 and then to compare the model predictions to measurements made throughout the Delta. Comparisons between the model and observations will provide insight into important mechanisms for phytoplankton productivity including physical and other influencing factors. The study will be a first step toward implementing priority research recommendations in the Delta Nutrient Research Plan. The study design leverages $24,000 of in-kind modeling resources from the Department of Water Resources and takes advantage of $900,000 of studies that are funded by other parties. Finally, this project implements a recommendation to increase data sharing among different models and monitoring programs.

Note that the budget originally included $35,000 for a subcontract with Deltares to write code to convert DWR's SCHISM model output to the Deltares Flexible Mesh (DFM) format. Deltares subsequently declined this task, and the planned contract amount was transferred to ASC labor. This change was approved by the Nutrients Subcommittee.

This study will be led by ASC with assistance from USGS through a subcontract. Additional subcontracts will needed with Deltares for model code development and external experts to either contribute to the final report or review it. The specific expertise needed to evaluate the results is not known at this time so these subcontractors are not explicitly listed. All subcontracts will be reviewed by the Financial Subcommittee before being executed.

Intercalibration Study for Chlorophyll Fluorescence Sensors in the Bay-Delta, Phase II - **$42,400**

Chlorophyll is an important water quality parameter for assessing the effects of nutrients and for fisheries management in the Bay-Delta. This study is the second phase of a multi-year effort to improve the accuracy, precision, and comparability of chlorophyll data collected in the Bay-Delta. Phase I planning has shown that variability in the methods used for measurement chlorophyll across the Bay-Delta is significant and that reducing this variance is of interest to a wide variety of monitoring agencies. In FY18/19, we plan to tackle a portion of the problem with a series of tasks to help understand and reduce the variance in the measurements of chlorophyll by in-situ sensors and laboratory methods. The planned tasks include: (1) assessing methods used by different monitoring programs; (2) performing field intercalibration exercises between programs; (3) organizing a laboratory intercalibration study; and (4) preparing a summary report through technical workgroup discussion. Funding is requested for SFEI-ASC and USGS to lead the study. The study leverages $105,000 of in-kind support from the Department of Water Resources and the US Bureau of Reclamation.

This study will be led by ASC with assistance from USGS through a subcontract. All subcontracts will be reviewed by the Financial Subcommittee before being executed. The Department of Water Resources and the U.S. Bureau of Reclamation will implement aspects of the project with in-kind resources.

Pesticides and Aquatic Toxicity - $211,578

The Pesticides Subcommittee requested funding for the first year of a four-year monitoring design for pesticides and aquatic toxicity in the Delta. The study will be led by ASC with assistance from USGS through a subcontract. Analyses of aquatic toxicity will be performed by the Aquatic Health Program Laboratory at UC Davis. All data management and quality assurance of toxicity data will be performed by staff of the State Water Resources Control Board's Office of Information Management and Analysis (OIMA).

The cost to the Delta RMP is summarized below:

USGS	Field sample collection and lab analysis	$155,517
AHPL	Toxicity Reporting	$15,063
ASC	Pesticides Data Management and Quality Assurance	$40,998
	Total	**$211,578**

Additional details of the pesticides study are shown in Attachment C. This monitoring project includes a $50,000 cost share from the US Army Corps of Engineers, a $13,704 cost share from the USGS for labor and travel expenses, and leverages up to $328,040 in funding from the Surface Water Ambient Monitoring Program to fund aquatic toxicity testing. A portion of the toxicity budget is a set-aside planning budget for toxicity identification evaluations (TIEs), which may not be necessary, depending on whether environmental samples test positive for toxicity.

Contaminants of Emerging Concern - $45,000

We anticipate beginning a pilot study for monitoring of CECs in FY19/20. The Steering Committee has approved $45,000 in funding to support planning and coordination to lay the groundwork for a successful study. We have planned two main tasks. The first task, "Coordination and planning," will support development of the detailed sampling and analysis plan for CEC monitoring, including selecting labs, setting up subcontracts, planning field work, and other tasks. The second task is to write a new Quality Assurance Program Plan covering the CEC monitoring project. Details are included in Appendix D.

Summary

On the following page, Table 5 summarizes planned expenses for monitoring and special studies authorized in FY18/19 and described in this workplan.

Table 5 Summary of Delta RMP FY18/19 Monitoring and Special Studies

Task, Subtask	ASC Labor	Subcontracts	Total
04. Nutrients Special Studies FY18/19			
A. Nutrients modeling study	$136,000	$50,000	$186,000
B. Chlorophyll intercalibration study	$6,350	$36,050	$42,400
	$142,350	**$86,050**	**$228,400**
05. Mercury Monitoring FY18/19			
A Data collection and analysis[1]	–	$242,130	$242,130
B. Mercury data management and QA	$29,930	–	$29,930
C. Technical oversight and coordination	$5,150	–	$5,150
	$35,080	**$242,130**	**$277,210**
06. Pesticides Monitoring FY18/19			
A. Field sample collection and lab analysis[2]	–	$155,517	$155,517
B. Toxicity reporting[3]	–	$15,063	$15,063
C. Pesticides data management and QA	$40,998	–	$40,998
	$40,998	**$170,580**	**$211,578**
07. CEC Monitoring Plan FY18/19			
A. Coordination and planning	$22,000	–	$22,000
B. QAPP amendments	$23,000	–	$23,000
	$45,000	**–**	**$45,000**
Total	**$263,428**	**$498,760**	**$762,188**

[1]Represents the cost to the Delta RMP. Moss Landing Marine Laboratory (MLML) has pledged $25,000 as in-kind services for mercury field sampling and analytical work.

[2]Cost to the Delta RMP. Includes a contribution of $50,000 by the US Army Corps of Engineers made directly to the USGS. Also includes an in-kind contribution by the USGS in terms of a cost-share on labor and supplies valued at $13,704.

[3]Toxicity lab work by the Aquatic Health Program Laboratory at UC Davis (AHPL) is funded directly by the State Water Resources Control Board through the Surface Water Ambient Monitoring Program (SWAMP).

Table 6 Budget details for monitoring and special studies

Task	Subtask	Expense Type	Budget	Description	Budget Justification	Deliverables
04. Nutrients Special Studies FY18/19	A. Nutrients Modeling Study	Labor	$136,000	SFEI-ASC staff time for analyst and modeler to initialize and run the biogeochemical model for WY2016, to handle data, collaborate with project partners, write and edit project report, and present findings. Additional task: write code to convert DWR's SCHISM model output to the Deltares Flexible Mesh (DFM) format.	80 hours for Lead Staff, 40 hours for Program Manager, 40 hours for Program Director, 32 hours for Environmental Analyst, and 480 hours for technical staff.	Final report on the Nutrients Modeling Study. Semi-annual progress reports to Delta RMP stakeholders. Converter code that will be useful for future modeling efforts.
		Sub-contracts	$50,000	USGS: analysis of modeled versus monitored data, and co-authorship of the final report Honoraria for consultants and external reviewers for peer review of the report.	USGS ($40,000); honoraria for consultants and external reviewers ($10,000)	
	B. Chlorophyll Inter-calibration Study	Labor	$6,350	SFEI-ASC staff time for study coordination and analysis. Tasks include assessment of methods, field intercalibration exercises, lab study, workgroup meetings, and writing a summary report.	10 hours for Program Manager, 16 hours for Program Director, and 10 hours for technical staff. (Note: Available funding covers startup phase only. Completion of this task depends on funding by the Bay Nutrient Management Strategy program.)	Task 1 deliverable: short report on the methods used to measure in-situ chlorophyll by different programs in the Bay-Delta. Task 2 deliverable: presentation to the workgroup on the intercalibration exercise to document intercomparability among chl-a measurement among different programs.
		Sub-contracts	$36,050	USGS subcontract for managing field data collection, analysis, collaboration through meeting attendance, and report writing.		Task 1: Assessment of in-situ chlorophyll methods in use Task 2: Presentation to workgroup on field intercalibration exercises Task 3: Report on laboratory intercalibration study Task 4: Summary report with recommendations for next steps

Task	Subtask	Expense Type	Budget	Description	Budget Justification	Deliverables
05. Mercury Monitoring FY18/19	A Data Collection and Analysis	Sub-contracts	$242,130	Field collection of fish and water samples and laboratory analyses by the Moss Landing Marine Laboratory (MLML).	Includes a $25,000 in-kind contribution from MLML	Year 3 Mercury Data Report
	B. Mercury Data Management and Quality Assurance	Labor	$29,930	Project Management and Coordination: setting up internal tracking system, communicate with DS team, PIs and labs on deliverables and issues. Data Management: manage collection info, create electronic data deliverable (EDD) templates, populate data into CEDEN templates from lab spreadsheet, log in Data sets, format data; Data Validation: Conduct data quality assurance procedures outlined in the Quality Assurance Project Plan (QAPP), data storage and release, upload final data CEDEN. Create summary tables for reporting.	Includes 45 hours for Data Manger, 92 hours for Technology Specialists, and 70 hours for Quality Assurance Officer	Mercury Fish and Water QA Summary Technical Memo
	C. Technical Oversight and Coordination	Labor	$5,150	Scheduling and coordinating field sampling activities, communication with lab staff, coordination with Mercury Subcommittee	24 hours for Lead Scientist	
06. Pesticides Monitoring FY18/19	A. Field sample collection and laboratory analysis	Sub-contracts	$155,517	USGS subcontract for field sample collection, laboratory analysis.		Pesticides Chemistry Lab Report (Report to the Delta RMP; not a formal USGS Data Series Report)
	B. Toxicity reporting	Sub-contracts	$15,063	Contract with the Aquatic Health Program Laboratory at UC Davis to submit detailed data package, attend meetings, and present preliminary results.		Provisional Data: A) SWAMP Toxicity Transformers (no charge) B) Bench Sheet Copies C) Reference Toxicant Control Charts D) Corrective Actions Table Meeting attendance and presenting preliminary results

Task	Subtask	Expense Type	Budget	Description	Budget Justification	Deliverables
06. Pesticides Monitoring FY18/19 (continued)	C. Pesticides Data Management and Quality Assurance	Labor	$40,998	Data receipt and data management; data validation, quality assurance and quality control. Troubleshooting and communication with labs. Making recommendations for corrective action if necessary. Publishing the data in the California Environmental Data Exchange Network (CEDEN).	Data Services Project Management and Coordination (70 hours); Data Receipt and Data Management (193 hours); Data Validation (88 hours); Data Storage and Release (46 hours); Toxicity data QA Summary (10 hours); 10% contingency	Pesticides chemistry QA Summary and Technical Memo; Spreadsheet of provisional data for sharing with Technical Advisory Committee; Data and metadata uploaded to CEDEN.
07. CEC Monitoring Plan FY18/19	A. Coordination and planning	Labor	$22,000	Development of the detailed sampling and analysis plan for CEC monitoring, including selecting labs, setting up subcontracts, planning field work, etc.	Includes 80 hours for environmental scientist, 20 hours for data services manager, 24 hours for QA officer, 16 hours for senior environmental scientist, and 48 hours for program manager.	CEC Sampling and Analysis Plan
	B. QAPP Amendments	Labor	$23,000	Creation of a new Quality Assurance Program Plan covering the CEC monitoring project. Includes: Compile Method Details from Laboratories; Prepare CEC Section in QAPP; Get Lab QAOs Approvals; Get SWAMP QAO Approval; Get TAC Approval; Get final signatures;	Includes 4 hours for program manager, 80 hours for an envionmental scientist, 40 hours for data services staff member, and 40 hours for the QA Officer.	Amended QAPP including complete description of CEC monitoring
	Total		**$762,188**			

Subcontractors

Table 7 lists the subcontractors included in the Delta RMP FY18/19 workplan. The contractors and service providers listed below are experienced and familiar with the Delta RMP and the Program's needs. Per the Delta RMP Charter, sole source justifications are provided in Appendix E for the subcontracts greater than $50,000, Moss Landing Marine Laboratory and the U.S. Geological Survey.

Table 7 Subcontractors

Contractor	Task	Budget Amount	Services
Moss Landing Marine Laboratory	5A	$242,130	Mercury Monitoring – field data collection and laboratory analysis
U.S. Geological Survey Biogeochemical Research Group (BGRC)	4A	$40,000	Nutrients Modeling Study: analysis of modeled versus monitored data, and co-authorship of the final report
USGS BGRC	4B	$36,050	Chlorophyll Intercalibration Study: analysis of modeled versus monitored data, and co-authorship of the final report
U.S. Geological Survey Pesticide Fate Research Group (PFRG)	6A	$155,517	Field sampling and laboratory analysis for pesticides
Aquatic Health Program Laboratory at UC Davis	6B	$15,063	Submission of detailed data packages, attendance at meetings, and presentation of preliminary results.
TBD - Honoraria	4A	$10,000	Honoraria for consultants and external reviewers of the Nutrients Modeling Study final report
McCord Environmental	2B	$19,200	TAC Co-Chair, meeting facilitation, coordination with stakeholders
Daphne Orzalli	2A, 2B	$4,800	SC and TAC meeting notes and summaries
Applied Marine Services	1A	$3,120	Statistical consultation on monitoring design and selection of sampling locations using the GRTS method.
Total		**$525,880**	

In-Kind Contributions

Financial reporting for the Delta RMP only includes funds managed by ASC. However, we make an effort to track in-kind contributions to the program. The success of the program relies on leveraging valuable contributions from partner agencies. Table 8 shows the value of planned in-kind contributions to the Delta RMP during FY18/19.

Table 8 Planned in-kind contributions to the Delta RMP in FY18/19.

Agency	Description	Value
Department of Water Resources (DWR) Bay Delta Office	In-kind contribution of WY2016 hydrodynamics model output	$24,000
Department of Water Resources (DWR) Office of Water Quality and Estuarine Ecology	6 staff to participate in the chlorophyll sensor intercalibration study (chl-a study)	$33,939
DWR North Central Regional Office	2 staff to participate in the chl-a study	$19,400
DWR Bryte Lab	Will analyze 9 water samples for the chl-a study. Each analysis has a value of $150/sample	$1,350
U.S. Bureau of Reclamation (USBR) Bay Delta Office	2 staff to participate in the chl-a study and purchase of needed equipment/supplies	$20,238
U.S. Geological Survey (USGS Biogeochemical Group)	Laboratory study of fluorescence sensors (Biogeochemical Group)	$30,000
U.S. Geological Survey (USGS, Pesticide Fate Research Group, PFRG)	Matching funds for pesticide monitoring project (10% of labor and travel)	$13,704
Moss Landing Marine Laboratory (MLML)	Cost share for mercury field sampling and laboratory analysis to cover staff time, equipment, and supplies	$25,020
State Water Resources Control Board, Surface Water Ambient Monitoring Program (SWAMP)	Direct funding to the Aquatic Health Program Laboratory at UC Davis covering aquatic toxicity laboratory testing	$328,040
US Army Corps of Engineers	Direct funding to USGS to cover a portion of the costs of pesticide sample collection and analysis.	$50,000
Total		**$545,691**

Overall Delta RMP FY18/19 Budget

The programmatic and scientific budgets for the Delta RMP are shown together in Table 9 on the next page. The total planned expense for the program in FY18/19 is $1,053,888.

The bar chart in Figure 2 shows how the planned program expenses for FY18/19 compares to budgeted expenses for the past four fiscal years.

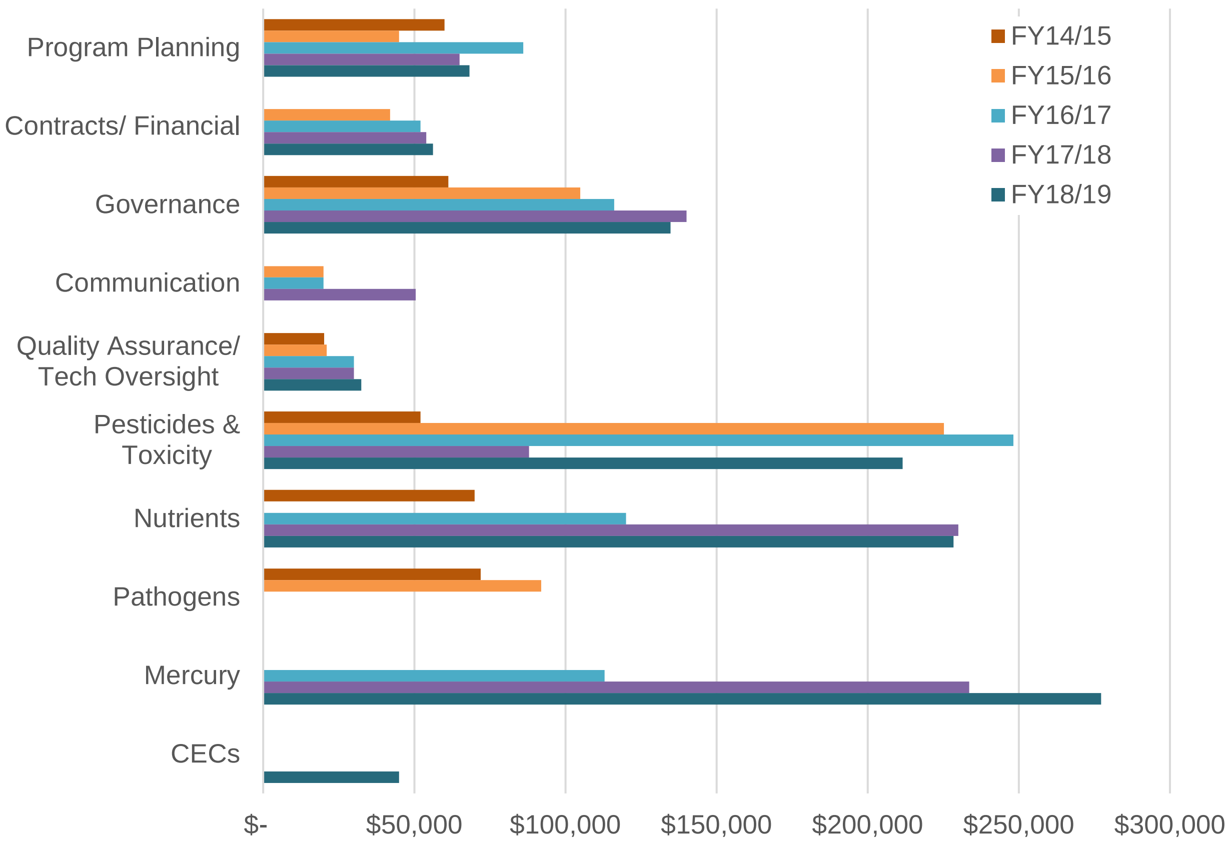


Figure 2 **Bar chart of budgeted expenses for the Delta RMP over last 4 fiscal years.**

Table 9 Delta RMP FY18/19 Overall Budget

Task	*Subtask*	Direct Cost	Labor	Subcontracts	Grand Total
01. Core Functions	A. Program Planning		$65,130	$3,120	$68,250
	B. Contract and Financial Management	$500	$55,650		$56,150
01. Core Functions Total		$500	$120,780	$3,120	$124,400
02. Governance	A. SC meetings		$36,000	$2,400	$38,400
	B. TAC meetings		$37,800	$21,600	$59,400
	C. Technical Subcommittees		$37,000		$37,000
02. Governance Total			$110,800	$24,000	$134,800
03. Quality Assurance	A. Quality Assurance		$17,500		$17,500
	B. Technical Oversight and Coordination		$15,000		$15,000
03. Quality Assurance Total			$32,500		$32,500
04. Nutrients Special Studies FY18/19	A. Nutrients Modeling Study		$136,000	$50,000	$186,000
	B. Chlorophyll Intercalibration Study		$6,350	$36,050	$42,400
04. Nutrients Special Studies FY18/19 Total			$142,350	$86,050	$228,400
05. Mercury Monitoring FY18/19	A Data Collection and Analysis			$242,130	$242,130
	B. Mercury Data Management and Quality Assurance		$29,930		$29,930
	C. Technical Oversight and Coordination		$5,150		$5,150
05. Mercury Monitoring FY18/19 Total			$35,080	$242,130	$277,210
06. Pesticides Monitoring FY18/19	A. Field sample collection and laboratory analysis			$155,517	$155,517
	B. Toxicity reporting			$15,063	$15,063
	C. Pesticides Data Management and Quality Assurance		$40,998		$40,998
06. Pesticides Monitoring FY18/19 Total			$40,998	$170,580	$211,578
07. CEC Monitoring Plan FY18/19	A. Coordination and planning		$22,000		$22,000
	B. QAPP Amendments		$23,000		$23,000
07. CEC Monitoring Plan FY18/19 Total			$45,000		$45,000
Grand Total		$500	$527,508	$525,880	$1,053,888

Attachment A Nutrients Special Projects

Delta RMP Special Study Description

Intercalibration Study for Chlorophyll Fluorescence Sensors in the Bay-Delta, Phase II

Summary:
Chlorophyll is an important water quality parameter for assessing the effects of nutrients and for fisheries management in the Bay-Delta. This study is the second phase of a multi-year effort to improve the accuracy, precision, and comparability of chlorophyll data collected in the Bay-Delta. Phase I planning has shown that variability in the methods used for measurement chlorophyll across the Bay-Delta is significant and that reducing this variance is of interest to a wide variety of monitoring agencies. In FY18/19, we propose to tackle a portion of the problem with a series of tasks to help understand and reduce the variance in the measurements of chlorophyll by in-situ sensors and laboratory methods. The proposed tasks include: (1) assessing methods used by different monitoring programs; (2) performing field intercalibration exercises between programs; (3) organizing a laboratory intercalibration study; and (4) preparing a summary report through technical workgroup discussion. Funding is requested for SFEI-ASC and USGS to lead the study. The study leverages $147,400 of in-kind support from the Department of Water Resources, the US Bureau of Reclamation, and the San Francisco Bay Nutrient Management Strategy.

Planned Expense: $42,400

Oversight Group: Delta RMP Nutrients Technical Subcommittee

Proposed by: SFEI-ASC, USGS, DWR, and USBR

Background

Accurate, precise measurements of phytoplankton biomass are critical to inform important management questions about productivity, nutrient management, and fisheries. Chlorophyll concentration is a widely-accepted proxy for phytoplankton biomass. There are presently more than 50 moored chlorophyll sensors using in-situ fluorescence in the Bay-Delta, belonging to networks maintained by the U.S. Geological Survey (USGS), Department of Water Resources (DWR), and others (Figures 1, 2, and 3). Prior to now there has been no effort to ensure that the groups making these measurements are using calibrations, sampling methods, and data processing techniques that ensure comparable results. Ensuring data comparability will save money and time, and will provide managers with better, high-resolution data for the entire estuary.

Therefore, to increase the utility and improve our return on the considerable effort to produce these data, the Delta Regional Monitoring Program and the San Francisco Bay Nutrient Management Strategy Science Program are jointly funding a project with the goal of improving the comparability of the chlorophyll data collected by different programs across the region. While a seemingly simple task, achieving this goal requires overcoming several technical barriers to apply common approaches for sensor acceptance and performance criteria, sensor calibration, performance validation, data collection, data quality assurance, data management, and data access.

In FY17/18, the Delta RMP and the Nutrient Management Strategy each contributed $15,000 for SFEI-ASC to organize the stakeholders, conduct some initial analyses, and to develop a detailed workplan for FY18/19.

The stakeholder outreach process revealed a broad interest from many agencies in:

- Standardizing, improving processes
- Having data from different programs be interoperable
- Improving relationship between in-situ and lab chlorophyll-a
- Coordination
- Improving data accessibility

The survey of 13 monitoring programs found that a variety of methods are being used by the different programs especially in the areas of sensor settings, calibration procedures, sensor cleaning, and QA/post-processing. The method differences were significant enough to make comparing data from different programs difficult. For example, some of the programs conduct 2-point calibrations, others perform a single point test at zero, and others do no calibration check. The laboratories performing extracted chlorophyll-a analyses use two fundamentally different methods (spectrophotometry and fluorometry).

Finally, analysis of measurements from the different programs data showed a large amount of variability in chlorophyll fluorescence response (differences as much as a factor of two) between regions of the Bay-Delta and between programs (Figure 4). Variability of this magnitude impedes synthesis of data from across the Bay-Delta without using site-specific calibrations.

Overall, the effort in FY17/18 has shown that variability in the methods used for measurement chlorophyll across the Bay-Delta is significant and that reducing this variance is of interest to a wide variety of monitoring agencies. A conceptual model for variability in the chlorophyll fluorescence (Figure 5) provides a way to break this challenging problem into smaller tasks. In FY18/19, we propose to tackle a portion of the problem with a series of tasks to help understand and reduce the variance in the measurements of chlorophyll by in-situ sensors and laboratory methods.

This proposal was developed and reviewed by a workgroup with representatives from SFEI-ASC, USGS, DWR, US Bureau of Reclamation (USBR), and the Central Valley Regional Water Quality Control Board.

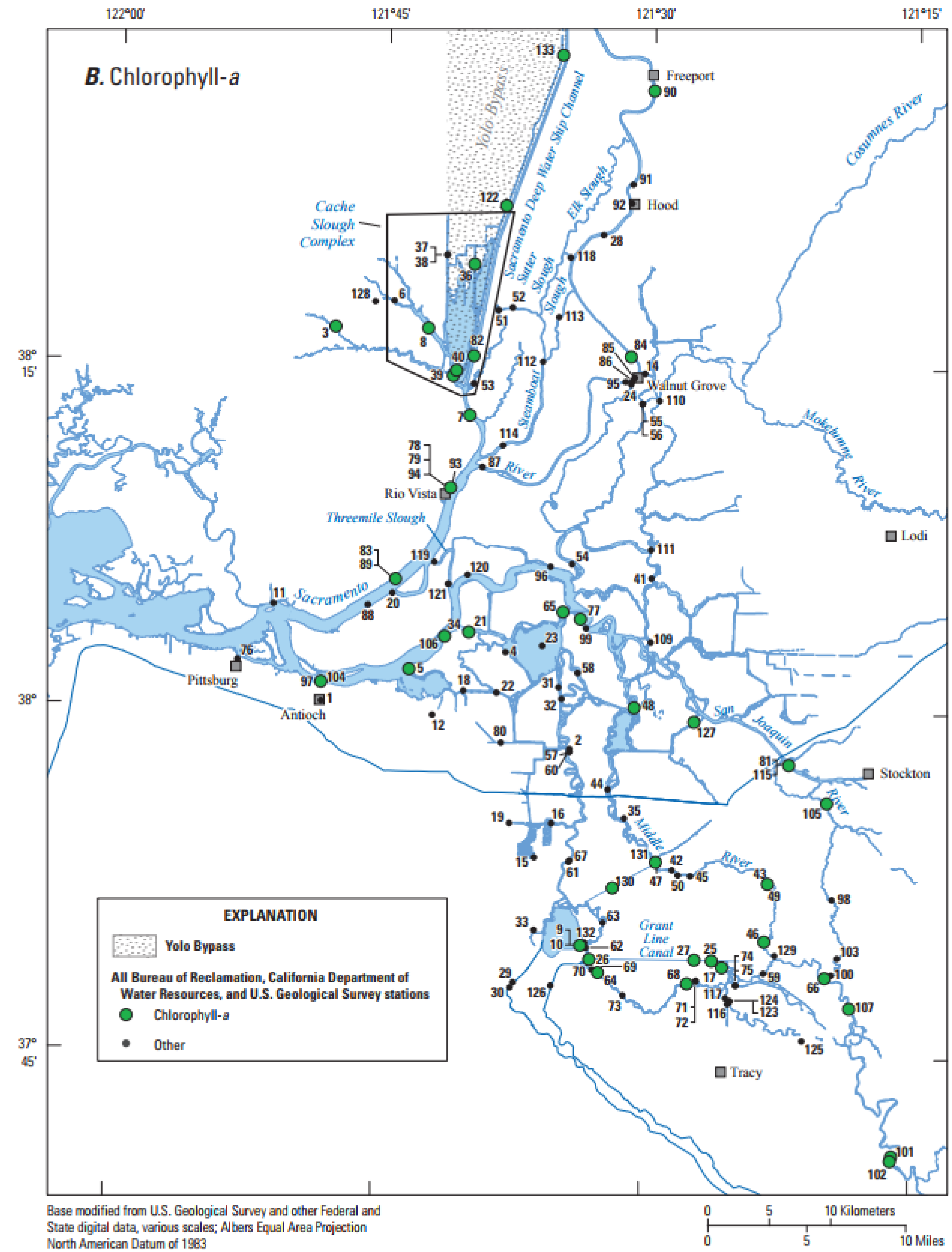


Figure 1: Chlorophyll fluorescence sensors in the Delta (from Bergamaschi et al., 2017)

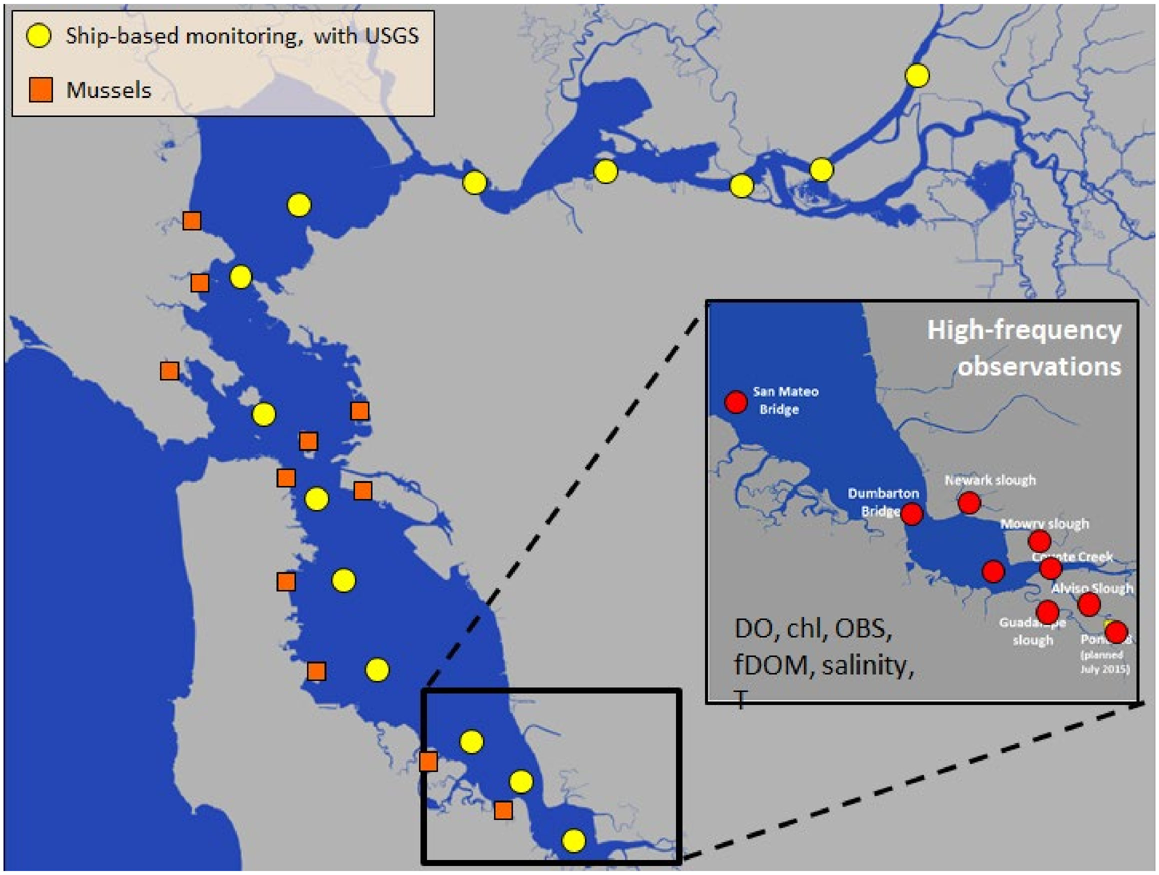


Figure 2: Chlorophyll fluorescence monitoring stations in the Bay. Continuous monitoring with moored sensors is performed at the red stations. Discrete measurements with sensors are made at ship-based monitoring sites (yellow) and mussel sites (orange). The graphic does not show all stations where chlorophyll fluorescence is monitored in the Delta, the Bay, and the coastal ocean.

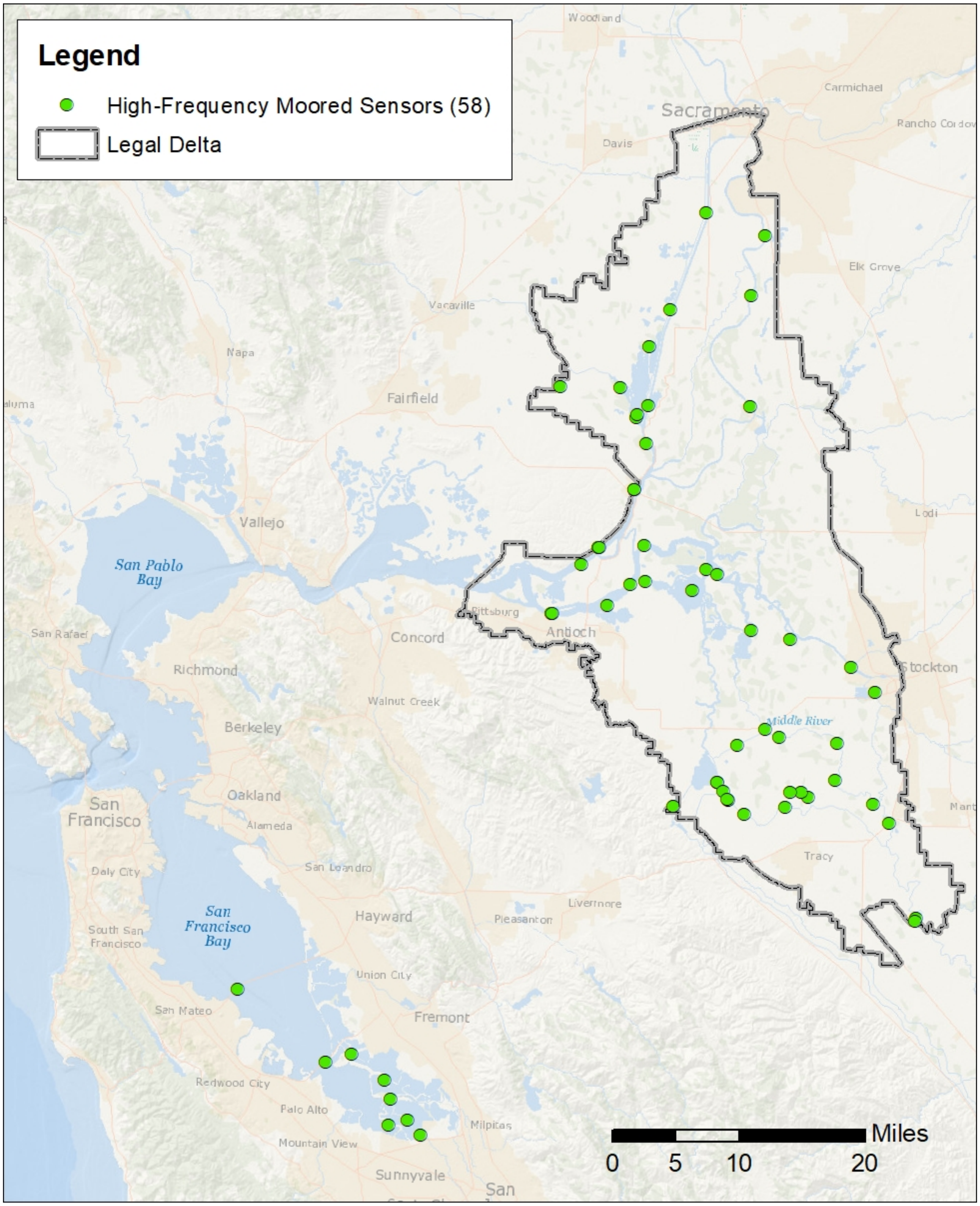


Figure 3: Stations with high-frequency moored sensors for chlorophyll that are managed by organizations that have agreed to participate in this study. Additional organizations will be invited to join the study.

RFU-Chla Ratio Varies With Program and Station

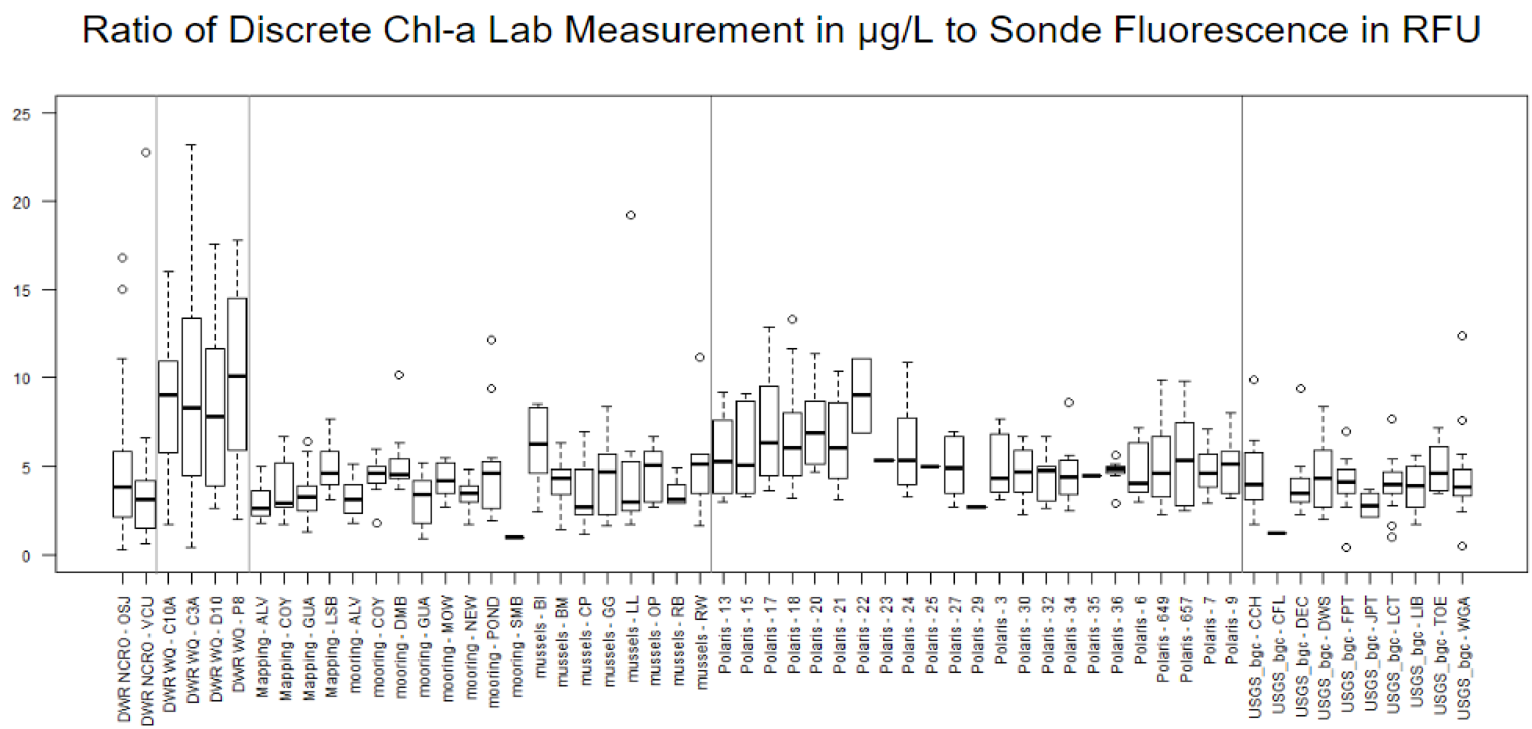


Figure 4: Ratio of sonde relative fluorescence units (RFU) from YSI EXO sondes to extracted chlorophyll measured in the laboratory across multiple programs and multiple locations in the Bay-Delta. The variance shown on this figure is from a combination of factors (see Figure 4). Natural variability among sites is evident when comparing different sites monitored by the same program. There can be natural differences between stations due to differences in salinity, tidal influence, and phytoplankton community. However, this graphic illustrates that some of the variance observed could be due to different protocols used by different programs.

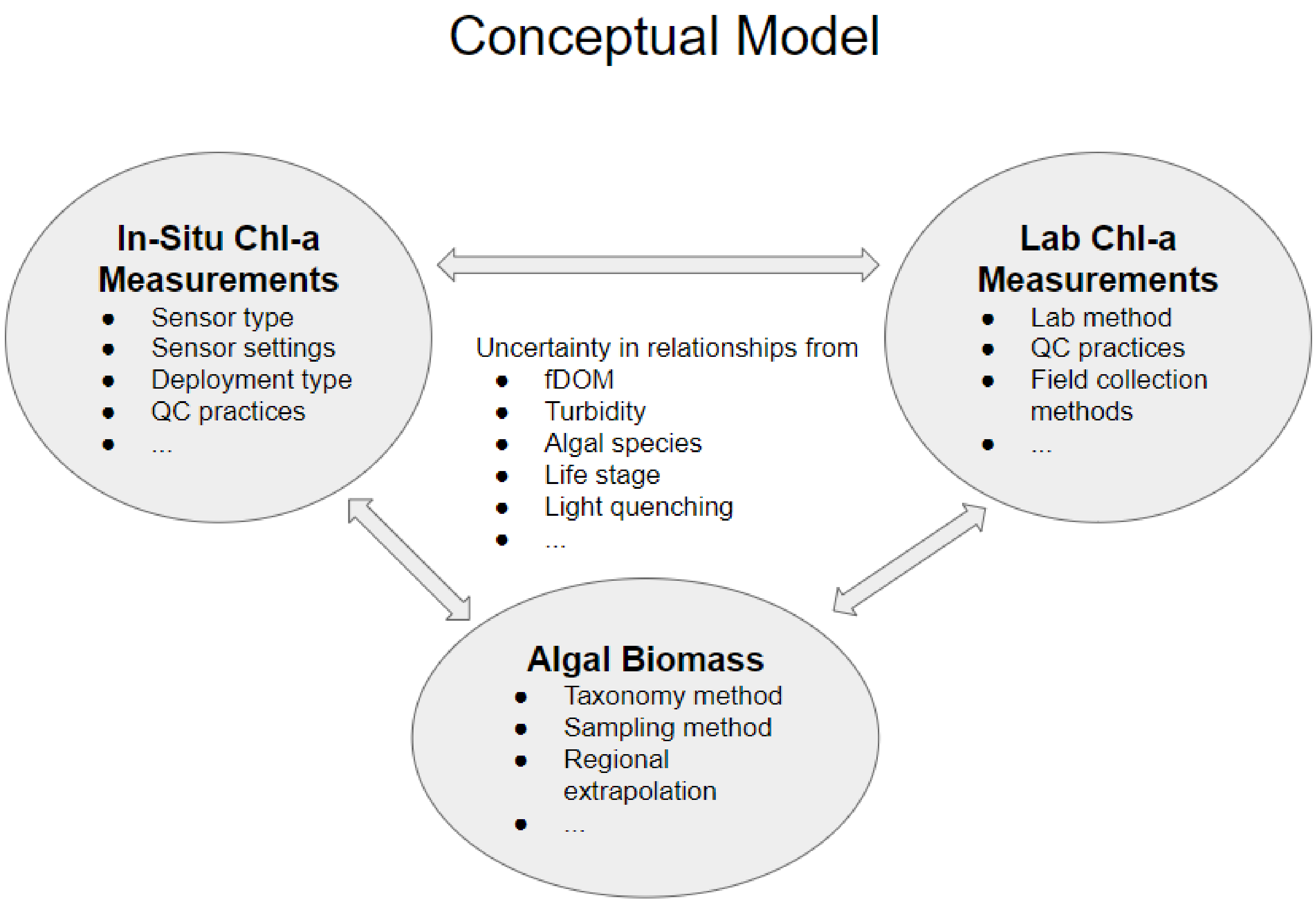


Figure 5: Conceptual model developed in FY17/18 for variance in extracted chlorophyll-a, in-situ chlorophyll fluorescence, algal biomass, and the relationships between these related parameters.

Study Objectives and Applicable RMP Management Questions

The objectives of the project and how the information will be used relative to the Delta RMP's management and assessment questions are shown in Table 1.

Table 1. Study objectives and questions relevant to Delta RMP management questions

Delta RMP Management Questions & Assessment Questions	Study Objectives	Example Information Application
Management Question: Is there a problem or are there signs of a problem? Assessment Question: How do concentrations of nutrients (and nutrient-associated parameters) vary spatially and temporally? (S&T1) This study is relevant to these questions because it will improve our ability to discern spatial and temporal trends in chlorophyll using data from multiple programs operating in the Bay-Delta.	Assess the differences in methods used by each program to measure chlorophyll. Determine whether differences in methods between programs result in significant variability in sensor and lab results for chlorophyll.	Water quality and resource managers will know the comparability of chlorophyll-a data from the major monitoring programs in the Bay-Delta. Data collection agencies will know which methods are important to address to improve the accuracy and precision of sensor and lab chlorophyll-a data in the Bay-Delta.

Approach

Task 1: Assessment methods used to measure in-situ chlorophyll fluorescence by different monitoring programs in the Bay-Delta

A small group of experts from the major programs (USGS, DWR, USBR, and SFEI-ASC) will summarize current practices for chlorophyll fluorescence measurements. At a minimum, the assessment will cover the following topic areas:

- Types of sensors and sonde equipment used
- Sensor settings
- Calibration
- Deployment and retrieval protocols
- Sensor servicing and cleaning
- Quality assurance
- Post-processing and data correction
- Reporting

The assessment will only cover <u>current methods</u> in use by programs; it will not survey past methods. Understanding the comparability of past methods to current methods is a priority for some agencies (e.g., DWR that has been monitoring since the 1980s) but it is beyond the scope of this effort.

A brief literature review will be conducted to ensure that this regional effort is informed by national and other relevant guidance. This review will not be exhaustive. It will focus on reports such as recent guidance/protocols for chlorophyll fluorescence sensors, previous intercalibration exercises with chlorophyll fluorescence sensors, and key foundational literature.

The deliverable for this task will be a short report on the results of the assessment, highlighting differences in methods for in-situ chlorophyll fluorescence between the major monitoring programs in the Bay-Delta, and the literature review. The report will become part of the final report for the overall project to be completed by the workgroup (Task 5).

For a schedule, the first step of this task will be prioritized to occur in July 2018. DWR has plans to deploy multiple new chlorophyll fluorescence sensors in the summer of 2018. Having initial information from the first step of this task will be helpful for setting up these sensors to be compatible with other major programs. The rest of the task will be completed during the first six months of the project.

Task 2: Coordinate intercalibration exercises that can be used to show the effects of different methods on sensor results

USGS will organize a series of field tests to measure chlorophyll fluorescence using different equipment and methods. Participants in these field tests will include at a minimum USGS, SFEI-ASC, DWR and USBR. The deliverable for this task will be a presentation to the workgroup.

Proposed Field Tests

- Side-by-side deployments by all programs that want to participate. Deployments would be in two locations that span a range of chlorophyll fluorescence and fDOM conditions (Mossdale and Montezuma Slough tentatively). Deployments would be during the summer and fall bloom period in 2018. A minimum of 4-6 weeks of side-by-side data will be collected. All sondes would be installed at the same depth in a common location and, at a minimum, will collect data on water temperature, specific conductance, dissolved oxygen, pH, turbidity, and chlorophyll fluorescence (and BGA and fDOM, if possible). The sondes will be serviced at whatever frequency each program normally uses. At the conclusion of the first side-by-side deployment, the organizers will decide if additional side-by-side deployments or a reproducibility study (described below) should be performed next.

Other Possible Field Studies

- Reproducibility study. This type of study tests for how much variance is due to operator, sonde type, or program protocols. Each program will send up to three technicians with their own calibrated sondes out on a boat together (USGS vessel). The boat will stop at a variety of sites. At each site, each technician will measure chlorophyll fluorescence (averaged over a duration of 10 minutes to reduce noise). Statistical analysis will be used to estimate the 95% confidence intervals (error bars) within and between technicians and programs.

Task 3: Intercalibration study for laboratory chlorophyll-a measurements

Laboratory measurements of extracted chlorophyll-a are used to calibrate and validate in-situ chlorophyll fluorescence measurements. Therefore, any effort to improve comparability in chlorophyll data needs to address variance in both in-situ and laboratory measurements. The proposed intercalibration study would show whether the laboratories in the region report similar results when given a split sample of the same water. Significant differences in the results between labs would trigger troubleshooting by chemists to find and fix the source of the variance.

A. <u>Inventory of the methods used by the major laboratories measuring chlorophyll-a in the Bay-Delta and secure their participation.</u>
   a. The known laboratories for major programs are DWR's Bryte Lab, USGS National Lab, SFSU Romberg Tiburon Center, and UC Davis. All laboratories will be allowed to be anonymous for the purposes of the study.
   b. A standardized survey instrument will be used to capture information on the field and analytical methods used and quality assurance procedures.

B. <u>Implement a "pre-coordination" round of analysis by participating laboratories</u>.
   a. For intercalibration study, the field samples will be collected by USGS during an opportunistic cruise.
   b. Samples will be collected during the summer growth period (July-Oct) at stations where chlorophyll-a concentrations are expected to exceed 5 ug/L.
   c. A total three sampling rounds will be conducted. For each sampling round, one large sample will be collected by peristaltic pump from 1 meter below the surface. This large sample will be delivered to DWR to be split

between the participating laboratories using a churn splitter. Each laboratory will receive triplicates of the sample in whatever format they usually require (e.g., a filter, a whole water sample, or something else). Each participating laboratory will receive three replicates of each sample.

d. For quality assurance, laboratories will also receive samples spiked with known concentrations of an algal culture. This process of "standard addition" will provide information on the accuracy of the methods used.

C. Analyze and report the results of the "pre-coordination" sampling round.

   a. Results of the study will be evaluated by comparing the mean and range of the triplicate samples from each laboratory. For a statistical evaluation of all the data across the three sampling days, the overall mean of all chlorophyll-a measurements from the same day will be subtracted from each individual result from the same day as a measure of deviation from the expected result. One-Way ANOVA will be used to determine whether there are any laboratories with statistically significant differences in the deviations.
   b. Quality Assurance. The measurement quality objectives for chlorophyll-a results by a single lab is presumed to be +/-30%. The goal of the study is to have the between-laboratory variance in this same range. A power analysis indicates that a sample size of 8 for each laboratory is needed to detect 50% differences between laboratories (e.g., for lab means of 10, 10, 10, and 5 ug/L with assumed error of 3 ug/L). Therefore, collecting 3 rounds of triplicate samples (9 samples total for each lab) will have sufficient sample size to detect between laboratory differences of management interest.

D. Organize coordination meeting with laboratories. Hold a meeting with representatives from the participating laboratories to discuss the results and coordinate regarding methods.

E. Prepare final report. The final report will summarize the results of the test, lessons learned, and recommendations.

Task 4: Convene a workgroup to summarize findings and recommendations

A workgroup of key practitioners will meet quarterly in FY18/19 to review the findings from the field and laboratory intercalibration studies. The workgroup meetings in FY17/18 have been highly productive and valued by the participants as a forum to learn from each other and to discuss important issues. The workgroup will review outcomes from the Tasks 1-3 and be responsible for developing a short report with conclusions and recommendations for next steps. Participants in the workgroup will include USGS-WSC, DWR, USBR, and SFEI/ASC at a minimum. At least one person who also sits on the Delta RMP Nutrients Subcommittee will be part of the workgroup. Participation will be open to any other interested parties.

The deliverable for this task will be a summary report with recommendations for next steps taking into account results from Tasks 1-4. The report will be submitted to the Delta RMP committees but is expected to be shared widely among Bay-Delta monitoring program once it is published.

Proposed Deliverables and Timeline

Table 2. Deliverables

Deliverable	Due Date
Task 1: Assessment of in-situ chlorophyll methods in use	Dec. 31, 2018 (final)
Task 2: Presentation to workgroup on field intercalibration exercises	Dec. 31, 2018
Task 3: Report on laboratory intercalibration study	March. 31, 2019
Task 4: Summary report with recommendations for next steps	April 30, 2019 (draft) June 30, 2019 (final)

Table 3. Timeline

	2018						2019					
Task	J	A	S	O	N	D	J	F	M	A	M	J
Task 1 - Assessment of Methods	■	■	■	■	■	X						
Task 2 - Field IC Exercises	■	■	■	■	■	X						
Task 3 - Lab IC study	■	■	■	■	■	■	■	■	X			
Task 4 - Workgroup Meetings			X			X			X			X
Task 4 - Summary Report							■	■	■	X	■	X

X = Deliverable due
■ = Activity

Budget

Table 4 shows the estimated costs for this special study.

Table 4. Proposed Budget

Task	Funding Requested for USGS	Funding Requested for SFEI-ASC	Total Funding Requested	In-Kind Contributions (details in justification)
Task 1 - Assessment of Methods	$5,000	$0	$5,000	DWR, USBR
Task 2 - Field IC Exercises	$6,750	$0	$6,750	DWR, USBR
Task 3 - Lab IC Study	$4,300	$0	$4,300	DWR, USBR
Task 4 - Workgroup Meetings	$10,000	$0	$10,000	DWR, USBR
Task 4 – Summary Report	$10,000	$6,350	$10,000	DWR, USBR
Total Funding Requested	**$36,050**	**$6,350**	**$42,400**	NMS
Leveraged In-Kind Contributions				**$104,927**

Budget Justification

Project Costs

Task 1

- USGS will manage this task and prepare a summary report. The cost for this effort is $5,000 (60 hours, mostly project manager time).

Task 2

- USGS will manage the field data collection for this task. The cost for this effort is: $5,750 (56 hours, mostly technician time) + $1,000 for boat, vehicle, and fuel expenses.
- SFEI-ASC will analyze the data from the field exercises and prepare a presentation with the results. The cost for this effort is $5,250 (48 hours of effort, mostly technician time).

Task 3

- SFEI-ASC will coordinate the laboratory intercalibration study and prepare a short summary report with the results. The cost for this effort is $10,000 (70 hours of effort, mostly technician time).
- Up to $3,500 of direct costs are budgeted for sample shipping, supplies, and lab fees. If laboratories agree to participate for free, costs will be reduced.

- USGS will collect the field samples for the field study and be responsible for shipments to the laboratories. The cost for their participation is $3,300 (40 hours mostly project manager time) +$1,000 for boat, vehicle, and fuel expenses.

Task 4

- SFEI-ASC will organize and facilitate 4 quarterly meetings of the workgroup. Assuming 20 hours to prepare and run each meeting (80 hours) plus 40 hours for project management for a total cost of $20,000.
- SFEI-ASC will also contribute to, edit, and ensure completion of the final report (40 hours) for a total cost of $10,000.
- USGS will participate in 4 quarterly meetings and be the lead author in the final report. Total funding required for these tasks is $20,000 (combination of senior scientist and project manager time). This total cost has been split as $10,000 for the workgroup meetings and $10,000 for the report.

Leveraged Funds and In-Kind Contributions

Leveraged funds are cash contributions from another source that pay for a part of the scope of work. In-kind contributions are staff time or resources (e.g., boat time, lab analyses) that are contributed to the project to complete the scope of work.

- The DWR Office of Water Quality and Estuarine Ecology has authorized 6 staff to participate in the study, which is an in-kind contribution of $33,939.
- The DWR North Central Regional Office has authorized 2 staff to participate in the study, which is an in-kind contribution of $19,400.
- The DWR Bryte Lab will analyze 9 water samples for Task 4. Each analysis has a value of $150/sample. Therefore, this service is an in-kind contribution of $1,350.
- The USBR Bay Delta Office has authorized 2 staff to participate in this study and purchase of needed equipment/supplies. This is an in-kind contribution of $20,238.
- The San Francisco Bay Nutrient Management Strategy has agreed to contribute $42,400 toward this effort to fund ASC labor.

USGS is also funding a laboratory study on “Developing corrections for observed biases on in situ chlorophyll fluorometers used in real time monitoring”. This study is directly related to the objectives of this study. Therefore, its value of $30,000 is also considered leveraged funds.

Reporting

The final deliverable from this project will be a technical report to the Delta RMP with the results from FY18/19 tasks and recommendations for future work. The lead author for the study will be USGS but the report will be *published* by SFEI-ASC. Representatives from other participating organizations will be co-authors. The report will be prepared in the form of a manuscript to facilitate publication of some or all of the findings in the peer-reviewed literature.

Optional Tasks for Future Funding

Achieving the high level goals of this study is expected to take several years. Accordingly, the proposed tasks for FY18/19 do not cover the full range of effort that is needed. The FY18/19 tasks will be useful to understand the scope of the problem, not necessarily to diagnose its causes. The project team anticipates the following tasks will be needed in FY19/20 plus recommendations that come out of the FY18/19 tasks. Furthermore, maintaining consistency and compatibility of water quality monitoring methods in the Delta must be an ongoing effort if it is to succeed. We envision an annual "Bay-Delta Monitoring Training Academy" where technicians can maintain proficiency in standard methods and share innovations.

Extension of Task 2: Coordinate intercalibration exercises that can be used to show the effects of different methods on sensor results

- Share equipment between programs, e.g., exchange of sensors and calibration check standards.
- Embed field crews from different programs to help identify where field methods differ and to share knowledge.
- Purchase 3 probes (sequential serial numbers) for all programs to check for variance in identical sensors and to remove variance from sensors of different ages.

Extension of Task 3: Intercalibration study for laboratory chlorophyll-a measurements

- Implement a "post-coordination" round of analysis by participating laboratories. The approach for this study would be the same as for the "pre-coordination" round. The samples will be collected in April and May 2019. The purpose of the post-coordination sampling round is to show improved correspondence between laboratories after coordination.

Analyze existing data to understand the magnitude of factors affecting chlorophyll fluorescence measurements

- For this task, existing data will be analyzed to understand the magnitude of the impact of other factors on chlorophyll fluorescence measurements. The effects that will be investigated are deployment depth, non-photochemical quenching, fDOM, and turbidity. The deliverable for this task will be a presentation to the workgroup.
- To understand if there is a large offset in chlorophyll fluorescence depending on the depth of the sensor, analyze profile data at sonde locations collected by USBR in the Deep Water Ship Channel (5 years of data). This dataset spans the range of vertical mixing conditions that are likely to be encountered in the Delta. The question to be addressed is: Do measurements of chlorophyll fluorescence at the surface or at the bottom need to be adjusted to be representative of the overall water column in Bay-Delta channels? At all sites? At certain types of sites?
- To understand if non-photochemical quenching (NPQ) is an important factor, analyze data collected during the day and the night (including grab samples for laboratory analysis from USBR) within the same 24-hour period and with tidal correction. The question to be addressed is: Does NPQ cause enough of an effect in the Bay-Delta that chlorophyll fluorescence data needs to be correct for this factor? If there is an important effect, one solution is to only use data collected at night.
- Analyze historic datasets where fDOM and turbidity have been measured to determine the size of the effect that these water quality parameters have on the

measurement of chlorophyll fluorescence. It has already been established that these parameters do affect chlorophyll fluorescence measurements. In some cases, fDOM sensors have direct interference with fluorometers. However, the magnitude of this effect and recommendations for correcting for it need to be determined. The question to be addressed is: How large of an effect do fDOM and turbidity have on chlorophyll fluorescence measurements in the Bay-Delta? Laboratory experiments are needed to investigate direct “cross talk” between fluorometers and fDOM sensors. That type of experiment is not proposed for this study.

Develop standardized methods for in-situ fluorometers

- Standardized methods would improve the consistency of data collection across the Bay-Delta. If the methods assessment (Task 1) and side-by-side deployments (Task 2) indicate the need for standardization and the major monitoring programs are willing to change their protocols, then a methods manual could be developed.

Training for water quality monitoring technicians

- Hold a training for larger audience of technicians to disseminate the lessons learned and common field protocols.

Analyze and collect data to relate chlorophyll fluorescence data to phytoplankton biomass

- A long-term goal is to be able to use chlorophyll measurements to make accurate assessments of phytoplankton biomass to inform important management questions about productivity, nutrient management, and fisheries. The FY18/19 workplan is focused on improving the comparability of just the chlorophyll measurements. In order to be ready for the next phase of the study, data to relate chlorophyll to actual phytoplankton biomass should be analyzed. Some data are already being collected as part of other studies (e.g., picoplankton and taxonomy at some USGS stations). Additional data may need to be collected in other locations to round out the dataset. Adding more sensors to some moored stations to create “superstations” where the relationships between these sensors and chlorophyll fluorescence is another option. Interpretation of phytoplankton taxonomy data will require expanding the expertise in the workgroup to cover this discipline.

References

Bergamaschi, B.A., Downing, B.D., Kraus, T.E.C., and Pellerin, B.A., 2017, Designing a high-frequency nutrient and biogeochemical monitoring network for the Sacramento–San Joaquin Delta, northern California: U.S. Geological Survey Scientific Investigations Report 2017–5058, 40 p., https://doi.org/10.3133/sir20175058.

Delta RMP Special Study Description

Merging High-Frequency Water Quality Data and Models to Gain Insights into the Factors Regulating Phytoplankton Blooms in the Delta in WY2016

Summary:
For this study, we plan to combine a hydrodynamic-biogeochemical model of the Delta in WY2016 with water quality measurements in order to understand what caused large phytoplankton blooms in this year. The approach will be to apply a biogeochemical model developed for WY2011 to WY2016 and then to compare the model predictions to measurements made throughout the Delta. Comparisons between the model and observations will provide insight into important mechanisms for phytoplankton productivity including physical and other influencing factors. The study will be a first step toward implementing priority research recommendations in the Delta Nutrient Research Plan. The study design leverages $24,000 of in-kind modeling resources from the Department of Water Resources and takes advantage of $900,000 of studies that are funded by other parties. Finally, this project implements a recommendation to increase data sharing among different models and monitoring programs.

Estimated Cost: $186,000

Oversight Group: Delta RMP Nutrients Technical Subcommittee

Project Team: SFEI-ASC, USGS, DWR

Background

Nutrient management is high-profile issue in the Delta. Nutrients are among the first-order factors that shape phytoplankton productivity, which is important for understanding pelagic organism decline. The Sacramento Regional County Sanitation District is already investing over $1 billion in wastewater treatment upgrades to manage nutrients. The Central Valley Regional Board recently completed a draft Delta Nutrient Research Plan which listed harmful algal blooms, increased aquatic macrophytes, and low dissolved oxygen as other water quality concerns associated with nutrients (Cooke et al., in review).

For this study, we are planning a synthesis of monitoring and modeling tools to better understand the linkage between nutrients and the phytoplankton blooms that occurred in WY2016 taking into account physical and other factors. The approach is directly relevant to Research Recommendation MON1 from the Delta Nutrient Research Plan. This recommendation calls for monitoring to assess “physical, chemical, and biological factors affecting phytoplankton abundance and growth” (Cooke et al., in review). The combination of data synthesis and modeling planned for this project will provide insight into all of these factors.

This project is designed to take advantage of two existing efforts that are funded by other parties. The Regional Water Control Boards (RB2 and RB5), Sacramento Regional County Sanitation District, Delta Stewardship Council, and Central Contra Costa Sanitary District are funding a project to develop, calibrate, and validate a biogeochemistry model for the Delta-Suisun in WY2011 (a year with low productivity). SFCWA is funding a project to synthesize data related to phytoplankton blooms in the Delta in WY2016 (a year with higher productivity) and prior years. The total investment for these two projects is nearly $900,000.

The study design is to apply the WY2011 biogeochemical model to WY2016 to allow for comparison between model predictions and observations of phytoplankton during this year of lower rainfall and higher productivity (see Figures 1 and 2). The comparison between the model and observations will provide insight into important mechanisms for phytoplankton productivity. Finding a mutual set of model parameters that work for both ends of the spectrum in terms of productivity (i.e., years with low or high productivity) will also help to narrow down the choice of biogeochemical model parameters for the Delta, from which the WY2011 Delta-Suisun modeling effort can also benefit.

Finally, this project implements a recommendation from the white paper on modeling that was prepared for the Delta Nutrient Research Plan (Trowbridge et al, 2016). One concept from that report was that being able to share information between different modeling groups “would be economical, lead to more efficient model applications (shorter project timelines), and increase opportunities innovation because more resources would be available for modeling” (p.24-25). This study will put this concept into action by using hydrodynamics from DWR’s SCHISM finite element platform and biogeochemistry from the Deltares Flexible Mesh finite volume platform. The project will develop code to facilitate future data sharing across these two platforms. Further, it will promote the sharing of information between modeling efforts, monitoring and research to help streamline the integration of new findings in biogeochemical models.

Study Objectives and Applicable RMP Management Questions

The objectives of the project and how the information will be used relative to the RMP's high-level management questions are shown in Table 1.

Table 1. Study objectives and questions relevant to RMP management questions.

Delta RMP Management Question & Assessment Question	Study Objectives	Example Information Application
Management Question: Which sources and processes are most important to understand and quantify? Assessment Questions: SPLP1- "Which sources, pathways, and processes contribute most to observed levels of nutrients?" SPLP2 - "How are nutrients linked to water quality concerns such as harmful algal blooms, low dissolved oxygen, invasive aquatic macrophytes, low phytoplankton productivity, and drinking water issues?" A. "Which factors in the Delta influence the effects of nutrients on the water quality concerns listed above?"	Set up and run a coupled hydrodynamic and biogeochemical model to simulate the nutrients and phytoplankton in the Delta in WY2016 by combining WY2016 hydrodynamics with a biogeochemical model developed for WY2011. Compare the modeled results for nutrient concentrations and phytoplankton with the measured observations for WY2016. Synthesize important differences between the model and observations to understand the processes that need to be improved in the model. Analyze the modeled results for WY2016 to identify the major factors that caused the observed phytoplankton blooms in that year. Demonstrate data sharing between different model platforms.	This project will accelerate biogeochemical model development in the Delta. If predictions match reality, then modelers will have confidence that the model parameterization is broadly applicable. If not, then modelers will have insights into what processes need to be improved in the model. Managers and researchers will know more about process and factors (especially physical factors) that resulted in the large algae blooms in WY2016. Data collection agencies and modelers will know more about which monitoring stations are useful for validating models. Managers and modelers will gain experience and know the pros/cons of sharing data between model platforms.

Approach

<u>Task 1: Obtain hydrodynamic model input and output files for the Delta in WY2016.</u>

DWR will provide input and output files for WY2016 hydrodynamics from the SCHISM model. The hydrodynamics will be validated at multiple locations in the Delta for the following parameters: flow, water level, temperature and salinity. SFEI will work with Deltares to write code to translate the output files to match the requirement of Deltares DWAQ model input. This code is an investment because it can later be used to translate SCHISM output files for other water years.

This approach combines the extensive expertise from DWR on Delta hydrodynamic modeling as well as the power of Deltares Water Quality model (DWAQ) to predict sophisticated biogeochemical cycling processes in aquatic systems. Developing systems for sharing data across model platforms is consistent with the “community modeling” approach outlined in the Modeling Strategy White Paper (Trowbridge et al., 2016).

Due to the differences in the model platforms, there is a small amount of risk that the SCHISM model output cannot be translated to the Deltares DWAQ format. As a backup, if it is not possible to use the SCHISM model output, the funds can be redirected to a subcontractor to develop the WY2016 hydrodynamics for the Deltares Flexible Mesh model. Therefore, a first step for this task will be for DWR to provide the SCHISM model output for an earlier year (e.g., WY2011) so that Deltares can identify any major barriers right away.

<u>Task 2: Prepare boundary condition and validation data for the WY2016 biogeochemical model</u>

Measurements of nutrients and nutrient-related parameters in WY2016 are needed to evaluate the model predictions for this year. Fortunately, with funding from SFCWA, USGS is already compiling much of the data that are needed for the modeling. Therefore, for this task, USGS will provide the WY2016 data from USGS and DWR stations that they have compiled for their other project and SFEI will gather other relevant data not already in the USGS database. These data will be formatted to match the input needs for the model and reconciled among data sources, which is not part of the SFCWA effort.

The parameters of interest for discrete grab samples include: chlorophyll-a, ammonia, nitrate, phosphate, turbidity, and dissolved oxygen (and potentially others such as zooplankton biomass, benthic grazer data, silica, and organic nitrogen if available). These data will be formatted and incorporated into the database for Delta/Suisun Bay modeling.

The parameters of interest for high frequency, in-situ sensor data are: nitrate, turbidity, chlorophyll fluorescence, and dissolved oxygen. High frequency data collected by the USGS, DWR, USBR, and other agencies will be compiled. The quality of the high frequency data will be checked by comparing the measured high frequency data with the discrete sampling data at the same or nearby location or reviewing metadata on datasets that have already gone through this step.

The geographic focus of this project is the whole Delta (see Figure 3 for a map of stations that will be included in the study). Much of the data needed, especially in the North Delta, including Cache Slough, and the Central Delta, are already being compiled by USGS through the SFCWA-funded study. For that study, data will be aggregated from the following sources: (a) USGS continuous monitoring stations and underway measurements; (b) DWR continuous monitoring stations; (c) discrete sampling and analysis programs of USGS, IEP, DWR, USBR and RTC; (d) other data as suggested by the community. Data types include temperature, conductivity, pH, turbidity, dissolved oxygen nutrients, chlorophyll fluorescence, chlorophyll concentration, dissolved organic matter fluorescence, phytoplankton abundance, zooplankton abundance, stage, discharge, velocity, precipitation, PAR, K_d and others.

<u>Task 3: Apply the biogeochemical model that has been calibrated/validated for WY2011 to hydrodynamics in WY2016.</u>
A complete biogeochemical model[1] for WY2011 will be developed with funding from other sources by December 2018 (see timeline in Table 3). This model can be applied to WY2016 using the SCHISM hydrodynamic output (Task 1) and data prepared in Tasks 2. This application will not attempt to fully validate[2] the model for WY16 but rather provide some initial evaluation on the performance of the model by comparing the model results to what was observed (see Task 4).

<u>Task 4: Compare model predictions of biogeochemistry in WY2016 to observations.</u>
The water quality data compiled in Task 2 will be compared to the model predictions for WY2016 (Task 3). <u>*The comparisons will be made at stations in all areas of the Delta using a similar approach as the Delta-Suisun modeling project.*</u> In addition, the project will take advantage of the large quantity of new, high-frequency data that is available for the North Delta and Central Delta that is being synthesized for the SFCWA-funded project. The deliverable for this task will be a technical report with:

- Results from data quality checks and other QA/QC on the datasets
- Plots and statistics (e.g., correlation coefficients, root-mean-square-error, and bias) of the performance of the model compared to the observations for dissolved nutrient concentrations and chlorophyll concentrations at various locations throughout the Delta, such as:
    - Concentrations of dissolved nutrients and chlorophyll
    - Spatial distribution of dissolved nutrients and chlorophyll
    - Zones of bloom inception
    - Timing of bloom inception and senescence
- Plots of modeled results for WY2016
- Hypotheses to explain the differences between the biogeochemical model output and observed water quality. The explanations will consider mechanistic relationships between physical factors (such as flow), nutrients, grazers, and chlorophyll. The topics on this list can be investigated in more depth with

[1] Including all the modules for biogeochemical cycling (nutrient cycling, phytoplankton dynamics, benthic grazing, zooplankton, mineralization, and sediment fluxes, and empirical light field).
[2] Data from the boundary conditions will be used to initialize the model; data from interior Delta stations will be used to evaluate and validate the model performance.

scenario tests using a fully calibrated model in a second phase of the study.
- Insights from the model about processes and factors (especially physical factors) that resulted in the large algae blooms in WY2016 as well as inferred rates of nutrient transformation and uptake.
- The monitoring stations that appear to be especially useful for validating biogeochemical models.
- Lessons learned and the advantages and disadvantages of sharing data between model platforms.
- Code to translate the SCHISM hydrodynamics output files to match the requirement of Deltares DWAQ model input.

The final report for this study will benefit from, not overlap with, the related SFCWA-funded effort. The SFCWA-funded report (due in February 2019) will contain insights into factors that caused the WY2016 phytoplankton blooms based on statistical relationships between phytoplankton abundance and community structure with (a) nutrient concentrations, forms and ratios; (b) temperature; (c) light availability; (d) water source and history; (e) water velocity and wind (as a proxy for turbulence) and discharge; (e) estimated residence time; and (d) events such as stormflows, Yolo bypass outflows and water releases. In practical terms, these insights will give direction on where to look and what to look for in terms of model validation and dominant processes (Tasks 3 and 4). Similarly, the mechanistic modeling work will provide insights into processes that could not be determined from the statistical analysis. In this way, the two projects are complementary and synergistic.

For information on progress reporting, see the “Reporting” section later in this document.

Deliverables and Timeline

Table 2. Deliverables

Deliverable	**Due Date**
Task 1: Obtain and format WY2016 Hydrodynamics input and output files	December 31, 2018
Tasks 2 and 3: Progress reports (written) and verbal updates to Delta RMP Nutrient Subcommittee members and other stakeholders at quarterly meetings for the Delta-Suisun modeling project.	July 2018 January 2019 July 2019 January 2020
Task 4: Final Technical Report/Manuscript	March 31, 2020 (draft) June 30, 2020 (final)

Table 3. Timeline

	2018												2019												2020					
Task	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Task 1 - Hydrodynamics												X																		
Task 2 - Model Set Up																														
Task 3 - Model Application																														
Task 4 - Reporting							X						X						X						X		X			X
Related Studies																														
SFCWA Study																														
Data aggregation																														
Data analysis																														
Reporting																														
Delta-Suisun WY2011 Modeling																														
Stage 2																														
Stage 3																														
Stage 4																														
Stage 5																														
Stage 6																														

X = Deliverable due
= Activity

<u>Delta-Suisun Modeling Stages</u>
Stage 2: Building a complete biogeochemical modeling framework that includes nitrogen cycling, phytoplankton dynamics, grazing behavior, mineralization, and benthic processes.
Stage 3: Test runs with Stage 2 model. Identifying dominant processes. Refining input data and model structure.
Stage 4: Improve model performance by tuning biogeochemical coefficients.
Stage 5: Adding dissolved oxygen. Scenario testing to answer management questions.
Stage 6: Final reporting.

Budget

Table 4 shows the estimated costs for this special study.

Table 4. Budget

Task	Funding for USGS	Funding for SFEI-ASC	Funding for Contractors	Total Funding	In-Kind Contributions
Task 1 - Hydrodynamics	$0	$40,000	$0	$40,000	$24,000
Tasks 2 & 3 - Biogeochemical Model Set Up and Application	$20,000	$66,000	$0	$86,000	$0
Task 4 - Report	$20,000	$30,000	$10,000	$60,000	$0
Total Funding	**$40,000**	**$101,000**	**$45,000**	**$186,000**	
Leveraged In-Kind Contributions					**$24,000**

<u>Budget Justification</u>

Task 1
- DWR will provide the WY2016 hydrodynamics model in-kind.
- The funding is for $35,000 for an SFEI-ASC scientist-programmer to write code to convert DWR's SCHISM model output to the Deltares Flexible Mesh (DFM) format and $5,000 SFEI-ASC labor (40 hours of SFEI-ASC modeler time) to handle data transfers and provide oversight and direction to the programmer.

Tasks 2 & 3
- For SFEI-ASC: The funding is for 3 months of SFEI modeler time ($51,000) and 1 month of Environmental Analyst time ($15,000) to initialize and run the biogeochemical model for WY2016. This step will also include generating plots of model output versus observations.
- For USGS: The funding includes $20,000 to support participation in meetings to plan and evaluate integration of high-frequency data with model output, trouble shoot WY2016 data transfer issues, and assist with additional data compilation.

Task 4
- The final report will be a collaboration between SFEI, USGS, and DWR. SFEI-ASC will be the lead author.
- For SFEI: $30,000 is for 130 hours of SFEI-ASC technical staff time and 75 hours of Program Manager/Senior Scientist time.
- For USGS: $20,000 is for analysis of modeled versus monitored data, and co-authorship of the final report including time to present the findings to Delta RMP committees and respond to up to two rounds of comments. Funding will also support USGS participation in two project meetings: (1) Meeting to compare

monitored and modeled results and plan final steps; and (2) Meeting to finalize main conclusions for final report.

- An additional $10,000 is allocated for honoraria for consultants and external reviewers of the final report. The specific expertise needed to evaluate the results of this study is not known at this time. These funds make it possible to bring in experts in phytoplankton, zooplankton, benthic grazers, or another discipline on an as-needed basis. In addition, the funds could be used for expert reviewers of the final report. Potential reviewers could be: Stephen Monismith from Stanford University, Jim Cloern from USGS, Fei Chai from University of Maine, Wim Kimmerer from San Francisco State University, and Lisa Lucas from USGS. Obtaining an in-kind peer-review through CWEMF will also be pursued. Plans for the use of these funds will be discussed with the Delta RMP Nutrients Subcommittee in advance.

Leveraged Funds and In-Kind Contributions

Leveraged funds are cash contributions from another source that pay for a part of the scope of work. In-kind contributions are staff time or resources (e.g., boat time, lab analyses) that are contributed to the project to complete the scope of work.

- DWR will contribute the WY2016 hydrodynamic model output from SCHISM as well as input files with an approximate value of $24,000.

While not strictly “leveraging”, the project will use outputs from two other highly-complementary and well-timed studies as an effective launch pad to maximize the impact of this work.

- Delta-Suisun Modeling with funding from Regional Boards (RB2 and RB5), Central Contra Costa Sanitary District, Sacramento Regional County Sanitary District, and Delta Science Program ($800,000 in total).
- WY2016 Algal Bloom Analysis with funding from the State and Federal Contractors Water Agency ($83,700).

Optional Tasks for Future Funding

The project will initiate the process of gaining understanding on the mechanisms behind phytoplankton productivity in the Delta. For FY19/20, a second phase of the study could be conducted to:

- Fully validate the WY16 biogeoechemistry model.
- Perform alternative hypothetical scenario runs to isolate the contribution from each forcing factor on causing the bloom event in 2016.

Reporting

The final report will be prepared in a format such that it can be submitted for publication as a manuscript. This manuscript will be reviewed by the Delta RMP committees following the protocols in the Delta RMP Communications Plan. If the manuscript is delayed, a stand-alone technical report will be prepared for the Delta RMP.

Progress reports (written and verbal) will be provided at semi-annual meetings for the Delta-Suisun modeling project. The Delta RMP Nutrients Subcommittee will be invited to these meetings. Similarly, participants from other, related studies (Operation Baseline, SFCWA study, Delta Smelt Resiliency Study) will be invited to these meetings.

The project will be overseen by the Delta RMP Nutrients Subcommittee so there will be regular updates on progress in that forum.

References

Cooke, J., C. Joab, and Z. Lu. In review. Delta Nutrient Research Plan, Draft Report. Central Valley Regional Water Quality Control Board, Rancho Cordova, CA. January 2018.

Trowbridge, P.R, M. Deas, E. Ateljevich, E. Danner, J. Domagalski, C. Enright, W. Fleenor, C. Foe, M. Guerin, D. Senn, and L. Thompson. 2016. Recommendations for a Modeling Framework to Answer Nutrient Management Questions in the Sacramento-San Joaquin Delta. Report prepared for: Central Valley Regional Water Quality Control Board, Rancho Cordova, CA. San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA. Published online: https://www.waterboards.ca.gov/centralvalley/water_issues/delta_water_quality/delta_nutrient_research_plan/science_work_groups/2016_0301_final_modwp_w_appb.pdf.

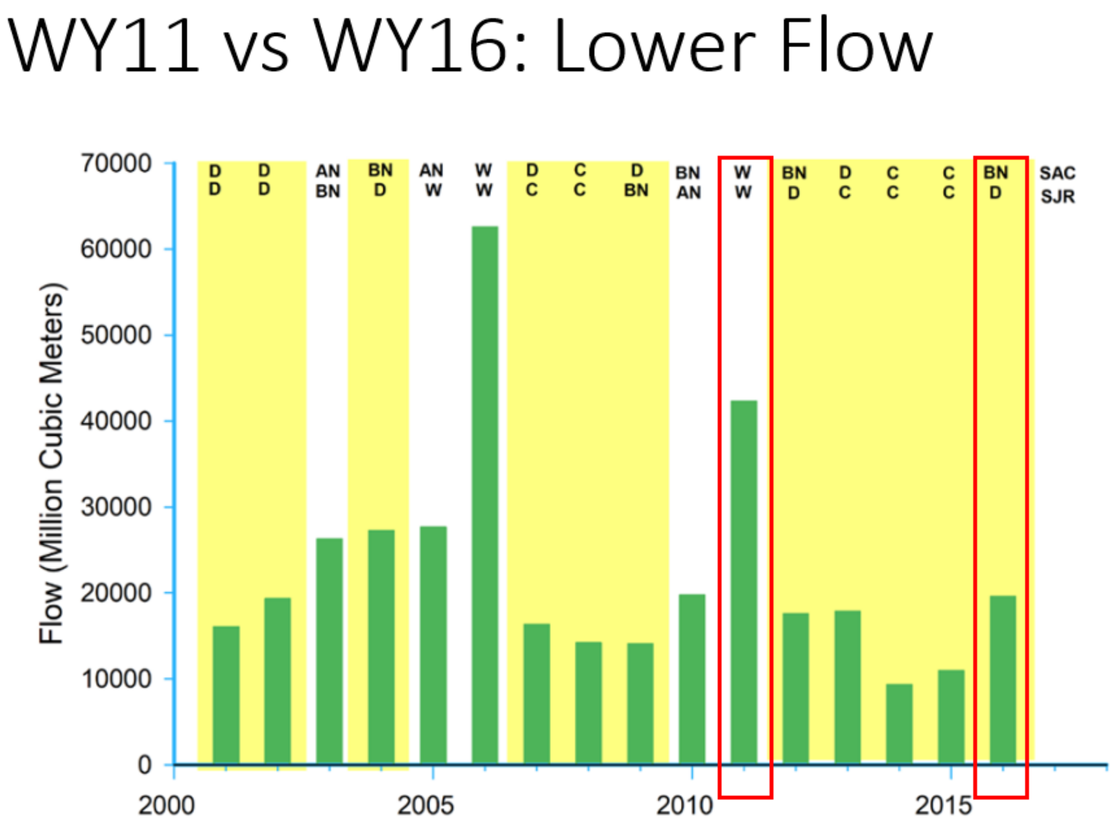


Figure 1: Total flow into the Delta. WY2011 and WY2016 are indicated with red boxes. WY2011 was characterized as a "wet" year. WY2016 was characterized as a "below normal" or "dry" year.

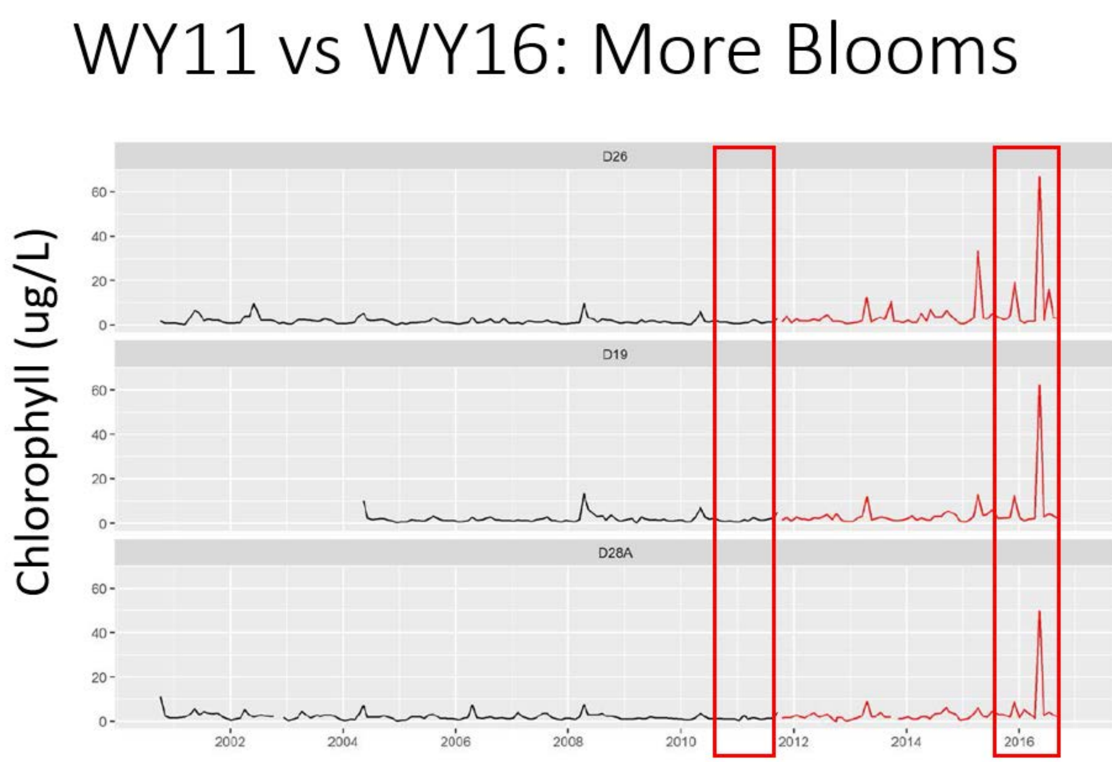


Figure 2: Timeseries of chlorophyll-a concentrations at DWR Environmental Monitoring Program stations in the Central Delta. WY2011 and WY2015 are indicated with with red boxes. WY2016 had significantly higher chlorophyll-a concentrations, indicative of algae blooms, than WY2011.

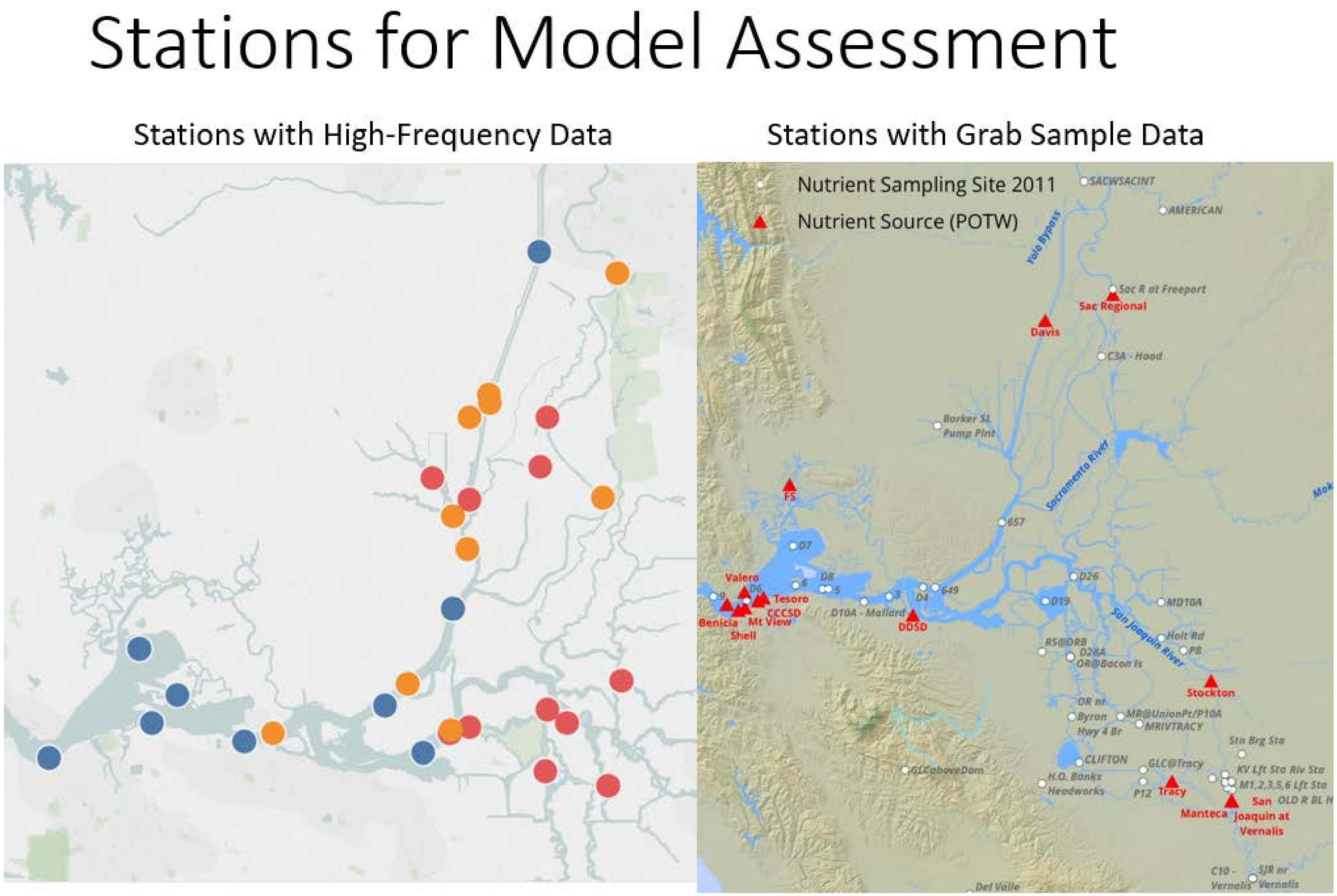


Figure 3: Stations with data that will be used for the modeling analysis. Model verification plots will be made for a subset of these stations covering all areas of the Delta.

Attachment B Mercury Monitoring

Mercury Monitoring for FY18/19 Workplan

Continued monitoring of sport fish and water will address the highest priority information needs related to implementation and revision of the Methylmercury TMDL (re-opening of the TMDL is tentatively scheduled for 2020). Annual monitoring of sport fish will firmly establish baseline concentrations and interannual variation in support of monitoring of long-term trends as a critical performance measure for the TMDL. Monitoring of water on a near-monthly basis will solidify the linkage analysis (the quantitative relationship between methylmercury in water and methylmercury in sport fish) in the TMDL and be valuable in verifying trends and patterns predicted by a numerical model of methylmercury transport and cycling being developed for the Delta and Yolo Bypass by the California Department of Water Resources (DWR) – this model will allow testing of various water management scenarios.

The cost for this workplan for mercury monitoring, with 8 water sampling events, is **$277,210**.

Should additional funds become available, higher-cost options have been scoped:

- 10 water sampling events: $323,798
- 9 water sampling events: $300,504

If additional funding becomes available during the fiscal year, the Mercury Subcommittee will discuss how to spread the events throughout the months of the year.

Management Drivers Addressed

Mercury monitoring addresses the Delta Methylmercury TMDL, which establishes goals for cleanup and calls for a variety of control studies and actions.

Assessment Questions Addressed

Two tiers of assessment questions have been defined for the mercury monitoring program. **Primary** assessment questions are those that are explicitly addressed by the monitoring and drive the monitoring design. **Secondary** assessment questions are addressed to some extent by the monitoring, but are not drivers of the monitoring design. The monitoring will contribute some information on but will not fully answer the secondary assessment questions.

Primary Assessment Questions

Status and Trends

ST1. What are the status and trends in ambient concentrations of methylmercury and total mercury in sport fish and water, particularly in subareas likely to be affected by major existing or new sources (e.g., large-scale restoration projects)?

ST1.A. Do trends over time in methylmercury in sport fish vary among Delta subareas?

Sources, Pathways, Loadings & Processes

SPLP1. Which sources, pathways and processes contribute most to observed levels of methylmercury in fish?

SPLP1.A. What are the loads from tributaries to the Delta (measured at the point where tributaries cross the boundary of the legal Delta)?

Fish-Water Linkage Analysis
(new priority question articulated by Mercury Subcommittee)

FWLA1. Are there key datasets needed to strengthen the technical foundation of contaminant control programs?

Secondary Assessment Questions

Status and Trends

ST1. What are the status and trends in ambient concentrations of methylmercury and total mercury in sport fish and water, particularly in subareas likely to be affected by major existing or new sources (e.g., large-scale restoration projects)?

ST1.B. How are ambient levels and trends affected by variability in climate, hydrology, and ecology?

Sources, Pathways, Loadings & Processes

SPLP1. Which sources, pathways and processes contribute most to observed levels of methylmercury in fish?

SPLP1.B. How do internal sources and processes influence methylmercury levels in fish in the Delta?

SPLP1.C. How do currently uncontrollable sources (e.g., atmospheric deposition, both as direct deposition to Delta surface waters and as a contribution to nonpoint runoff) influence methylmercury levels in fish in the Delta?

Forecasting Scenarios

FS1. What will be the effects of in-progress and planned source controls, restoration projects, and water management changes on ambient methylmercury concentrations in fish in the Delta?

Data Quality Objectives/Null Hypothesis

The initial and preliminary data quality objective (DQO) is the ability to detect a trend of mercury in fish tissue of 0.040 ppm/yr. This DQO can be refined when additional data are available. The null hypothesis is that there is no trend. MQOs are identical to those used in other mercury studies throughout the state and the country for determinations of impairment and trend detection. These MQOs generally call for indices of accuracy and precision to be within 25% to 30% of expected values.

Monitoring to Support Implementation of the Methylmercury TMDL

Executive Summary

Continued monitoring of sport fish will address the highest priority information needs related to implementation and revision of the Methylmercury TMDL (re-opening of the TMDL is tentatively scheduled for 2020). Annual monitoring of sport fish will firmly establish baseline concentrations and interannual variation in support of monitoring of long-term trends as a critical performance measure for the TMDL. Monitoring of water on a near-monthly basis will solidify the linkage analysis (the quantitative relationship between methylmercury in water and mercury in sport fish) in the TMDL and be valuable in verifying trends and patterns predicted by a numerical model of methylmercury transport and cycling being developed for the Delta and Yolo Bypass by the California Department of Water Resources (DWR) - this model will allow testing of various land and water management scenarios.

Background and Motivation

Concentrations of methylmercury in fish from the Delta exceed thresholds for protection of human and wildlife health. The Methylmercury TMDL (Wood et al. 2010) is the driver of actions to control methylmercury in the Delta, establishing water quality goals and directing various discharger groups to conduct monitoring and implement measures to minimize methylmercury impairment of beneficial uses.

The TMDL established three water quality objectives for methylmercury in fish tissue: 0.24 ppm in muscle of large, trophic level four (TL4) fish such as black bass; 0.08 ppm in muscle of large TL3 fish such as carp; and 0.03 ppm in whole TL2 and TL3 fish less than 50 mm in length. Furthermore, the TMDL established an implementation goal of 0.24 ppm in largemouth bass at a standard size of 350 mm as a means of ensuring that all of the fish tissue objectives are met. Largemouth bass are widely distributed throughout the Delta and are excellent indicators of spatial variation due to their small home ranges. Past data for largemouth bass were a foundation for the development of the TMDL, including the division of the Delta into eight subareas. Monitoring of largemouth bass in these subareas therefore provides the most critical performance measure of progress in addressing methylmercury impairment in the Delta.

The TMDL describes a statistically significant relationship between the annual average concentration of methylmercury in unfiltered water and average mercury in 350 mm largemouth bass when data are organized by subarea. This linkage provides a connection, essential for management, between methylmercury inputs from various pathways (e.g., municipal wastewater, municipal stormwater, agricultural drainage, sediment flux in open waters, and wetland restoration projects) and impairment of beneficial uses. Because of this linkage, the TMDL established an implementation goal of 0.06 ng/L of unfiltered aqueous methylmercury. In response to TMDL control study requirements, the Department of Water Resources (DWR) is leading development of numerical methylmercury transport and cycling simulation models for the Delta and Yolo Bypass. Monitoring of aqueous methylmercury is therefore needed to:

1) better quantify the fish-water linkage that is the foundation of the TMDL,
2) evaluate attainment of the TMDL implementation goal,
3) support calculations of mercury and methylmercury loads and mass balances,
4) support development of mercury models for the Delta and Yolo Bypass, and
5) support evaluation of the fish data by providing information on processes and trends.

In FY 2016/2017 the Delta RMP initiated a methylmercury monitoring program for fish and water. Largemouth bass were collected in late summer 2016 (September) from six locations distributed across the subareas. Quarterly sampling of methylmercury and mercury (and ancillary parameters) in water at five locations began in August 2016.

In FY 2017/2018, methylmercury monitoring of fish and water continued. Funding was allocated to sample fish at six locations and water at six locations for eight months. The eight months to be sampled were to be the March-October period used for the linkage analysis in the TMDL. In late 2017, the Mercury Subcommittee decided that a more optimal use of the available funds would be to shift to sampling water at eight locations (adding locations in the West Delta and at the export pumps) and to add sampling in January and February (Table 1). The FY 2017/2018 plan also included funds for quarterly sediment sampling to support the DWR methylmercury modeling effort, and any future methylmercury modeling. *No further sediment sampling is planned at this time.*

Table 2 summarizes the sampling frequency over the first two years of Delta RMP mercury monitoring, in terms of the number of events and sites sampled and the total number of samples collected. Table 2 also shows the planned sampling frequency for FY18/19 and the desired sampling frequency in FY19/20.

Applicable Management Decisions and Assessment Questions

The Delta Methylmercury TMDL is the embodiment of management decisions for methylmercury in the Delta, establishing goals for cleanup and calling for a variety of control studies and actions. With providing information to support TMDL implementation in mind, the Mercury Subcommittee carefully considered, refined, and prioritized the assessment questions articulated by the Steering Committee and Technical Advisory Committee for mercury.

Two tiers of assessment questions have been defined for the mercury monitoring program. **Primary** assessment questions are those that are explicitly addressed by the monitoring and drive the monitoring design. Secondary assessment questions are addressed to some extent by the monitoring, but are not drivers of the monitoring design. The monitoring will contribute some information but will not fully answer the secondary assessment questions.

Primary Assessment Questions

One priority question for this initial phase of methylmercury monitoring is from the Status and Trends category of the DRMP management and assessment questions:

Status and Trends

ST1. What are the status and trends in ambient concentrations of methylmercury and total mercury in sport fish and water, particularly in subareas likely to be affected by major existing or new sources (e.g., large-scale restoration projects)?

ST1.A. Do trends over time in methylmercury in sport fish vary among Delta subareas?

Question 1A is a high priority for managers that relates to the TMDL, and is a primary driver of the sampling design for fish monitoring. Annual monitoring of fish mercury is urgently needed to 1) firmly establish a baseline for each Delta subarea and 2) to characterize the degree of interannual variation, which is essential to designing an efficient monitoring program for detection of long-term trends. In addition to addressing status and trends, this monitoring will establish a foundation for tracking the effectiveness of management actions - another category of the Delta RMP core management questions.

Sources, Pathways, Loadings and Processes

SPLP1. Which sources, pathways and processes contribute most to observed levels of methylmercury in fish?

SPLP1.A. What are the loads from tributaries to the Delta (measured at the point where tributaries cross the boundary of the legal Delta)?

A mass budget for methylmercury in the Delta is a critical element of the TMDL. The mass budget provides essential context for understanding the importance of inputs from discharges and internal sources and processes. Obtaining data to expand and update the dataset on methylmercury inputs to the Delta is a high priority to support TMDL refinement and implementation. Methylmercury export from the Delta is similarly an important component of the mass budget and a high priority information need.

Fish-Water Linkage Analysis
(new priority question articulated by Mercury Subcommittee)

FWLA1. Are there key datasets needed to strengthen the technical foundation of contaminant control programs?

Another priority question that will be addressed by this workplan relates to the linkage analysis discussed in the previous section, which is a key element of the technical basis for the TMDL. This question was not articulated in the core management questions and assessment questions established by the Steering Committee, but was nevertheless identified as a priority by the Mercury Subcommittee. Additional data on methylmercury in water is one of the key datasets needed to strengthen the technical foundation of the TMDL.

Secondary Assessment Questions

ST1. What are the status and trends in ambient concentrations of methylmercury and total mercury in sport fish and water, particularly in subareas likely to be affected by major existing or new sources (e.g., large-scale restoration projects)?

ST1.B. How are ambient levels and trends affected by variability in climate, hydrology, and ecology?

The time series for methylmercury in fish and water that are created to answer the primary assessment questions will also be influenced by variation in climate, hydrology, and ecology, and will provide information on the role of these factors. For example, the first two years of monitoring have already spanned the end of a prolonged drought and a high flow year, providing an opportunity to examine the impact of extreme variation in flow on methylmercury concentrations in fish and water.

Sources, Pathways, Loadings and Processes

SPLP1. Which sources, pathways and processes contribute most to observed levels of methylmercury in fish?

SPLP1.B. How do internal sources and processes influence methylmercury levels in fish in the Delta?

SPLP1.C. How do currently uncontrollable sources (e.g., atmospheric deposition, both as direct deposition to Delta surface waters and as a contribution to nonpoint runoff) influence methylmercury levels in fish in the Delta?

Forecasting Scenarios

FS1. What will be the effects of in-progress and planned source controls, restoration projects, and water management changes on ambient methylmercury concentrations in fish in the Delta?

These secondary assessment questions relating to Sources, Pathways, Loadings, and Processes and Forecasting Scenarios for this initial phase of methylmercury monitoring relate to one of the major control studies called for in the TMDL: an effort to combine modeling, field data, and laboratory studies to evaluate the potential effects of water project operational changes on methylmercury in Delta channels. The Department of Water Resources (DWR) is currently developing two mathematical models, one each for the Delta and Yolo Bypass, that will allow testing of various water management scenarios (DiGiorgio et al. 2016). These models will be useful in addressing this set of Delta RMP management questions. The opportunity to inform these models, which are being developed with a considerable investment of funding from the California Department of Water Resources (DWR), makes monitoring to address these questions a near-term priority for the Delta RMP. The water monitoring included in this workplan will generate data that are valuable for verifying trends and patterns predicted by the methylmercury models.

Approach

Fish Sampling

Design	7 fixed sites (Figure 1), largemouth bass only - adding a site in the West Delta in this round
Key Indicator	Annual average methylmercury in muscle fillet of 350 mm largemouth bass (or similar predator species), derived through analysis of 16 individual bass or other predator species at each location
Parameters	Total mercury*, Total length, Fork length, Weight, Sex, Moisture, Estimated age
Frequency	Annual
Schedule	Monitor through 2025 and then re-evaluate. Sample in summer or early fall.
Co-location	Water methylmercury (MeHg) and mercury (Hg) Other water parameters
Contractors	SFEI (design, data management, reporting), MLML (sample collection, chemical analysis, reporting)
Coordination	DWR, USGS (sampling of flow monitoring stations)

* Total mercury measured as proxy of methylmercury because methylmercury comprises more than 90% of the total mercury in fish.

Summary of Results to Date

Results from the first year of DRMP methylmercury monitoring are presented in the Year One Data Report (Davis et al. 2018). The report provides details on the sample collection and processing, chemical analysis, quality assurance, and the results. Highlights of the results are briefly discussed here.

Results from the first round of DRMP fish monitoring are presented in Figure 2, with data from prior fish sampling in or near these stations provided for context. Time series with more than three observations are available for four of the six locations. The existing time series are characterized by a high degree of inconsistency in locations, species, and sampling approach over time, highlighting the need to build a consistent dataset for trend evaluation. The data do suggest a preliminary answer to management question 1A. The data suggest a decline in concentrations at the San Joaquin River at Vernalis over the period of record, while concentrations appeared to be stable at the other three locations. Therefore, the data give a preliminary indication that trends do vary among the Delta subareas. Additional rounds of consistent sampling are needed to confirm this preliminary interpretation.

Water Sampling

Design	8 fixed sites (Figure 1) - adding sites for export from the Delta in this round (Mallard Island in the west Delta and the Delta Mendota Canal for a water project export site)
Key Indicator	March-October average total (unfiltered) methylmercury at each location
Parameters	• Total (unfiltered) methylmercury • Filtered methylmercury • Unfiltered total mercury • Filtered total mercury • Total suspended solids • Volatile suspended solids • Chlorophyll-a • Dissolved organic carbon (field filtered) • Total organic carbon **Field measurements:** • Dissolved oxygen • pH • Specific conductance
Frequency	8 events per year (6 bi-monthly events + 2 storm or winter events)
Schedule	Monitor through 2020 and then re-evaluate
Co-location	Sport fish sampling (at 7 of the sites, excluding Delta Mendota Canal) Other water parameters
Coordination	DWR, USGS (sampling of flow monitoring stations)

Summary of Results to Date

Results for March-October average total (unfiltered) methylmercury at each location for the first year of sampling are briefly summarized here. Data for the other water parameters are presented in the Year One Data Report (Davis et al. 2018).

Figure 3 presents long-term time series of March to October annual averages of total unfiltered MeHg concentrations for Delta RMP sites. Sacramento River concentrations have remained constant with good agreement between historic data and current data. Cache Slough 2016 concentration was lower than what was reported previously but the 2017 concentration was within historic ranges. No historic data are available for Little Potato Slough. Middle River MeHg concentrations were highly variable with 2016–17 concentrations within the range of historic data. The San Joaquin River 2016 MeHg concentration was lower than previously reported values. However, the 2017 measurement was the highest concentration ever reported for this site.

Data Quality

The measurement quality objectives (MQOs) for measurements of methylmercury and mercury in fish and water are shown in Appendix 1. These MQOs are the same as MQOs used in mercury studies throughout California, with statewide fish monitoring by the Surface Water Ambient Monitoring Program as a prominent example. The MQOs generally call for indices of accuracy and precision to be within 25% to 30% of expected values. Data of this quality are routinely used for determinations of impairment and trend detection throughout the state and the country. The variance attributable to the analytical process is one of the contributors to the overall variance observed in the data. This variance is therefore accounted for in the power estimates provided in the next section.

Power to Detect Long-term Trends - Fish Sampling

The power to detect interannual trends in largemouth bass mercury on a per site basis was evaluated using existing data. Even the best existing time series for the Delta have low statistical power to detect trends due to infrequent sampling and varying sampling designs of studies performed over the years (Figure 2). One of the goals of the initial phase of Delta RMP fish mercury monitoring is to obtain robust information on interannual variation to support future power analysis. As part of the mercury proposal for FY 2017/2018 we conducted a power analysis on the small amount of information presently on hand. Appendix 2 provides the methods and details on the results. This analysis will be updated after a few years of new data have accumulated.

Power analysis summary

Power for trend detection at a single site based on grand mean estimates of observed variance across sites. Pink shading indicates scenarios with greater than 80% power.

		10 Years		20 Years		30 Years	
Trend	N Fish/Yr	Annual	Biennial	Annual	Biennial	Annual	Biennial
0.010 ppm/yr	12	0.11	0.09	0.20	0.15	0.40	0.27
0.020 ppm/yr	12	0.13	0.13	0.44	0.27	0.81	0.60
0.030 ppm/yr	12	0.21	0.17	0.69	0.45	0.99	0.85
0.040 ppm/yr	12	0.29	0.19	0.88	0.61	1.00	0.98
0.010 ppm/yr	16	0.21	0.19	0.33	0.27	0.55	0.44
0.020 ppm/yr	16	0.27	0.24	0.65	0.46	0.93	0.77
0.030 ppm/yr	16	0.36	0.32	0.86	0.64	1.00	0.96
0.040 ppm/yr	16	0.47	0.36	0.97	0.82	1.00	1.00

These preliminary results indicate that increasing the number of fish per site would be effective in increasing power. With 16 fish per site and annual sampling, 80% power would be expected for several of the 20-year scenarios. Beginning with year 2 (FY 2017/2018) the design for fish monitoring was therefore being modified to include 16 fish per site. The monitoring results for the San Joaquin at Vernalis suggest that trends of up to 0.040 ppm/yr are possible. The results highlight the importance of initiating consistent time series.

Power Analysis - Water Sampling

Not applicable. The primary objectives of the water sampling are to strengthen the linkage analysis and support model development. The water monitoring is not intended as a tool for long-term trend monitoring.

Reporting/Deliverables

Deliverable	Due Date
Draft Data Report on Year 2 (FY 17/18) Provisional FY17/18 dataset for review by TAC	December 2018
Final Data Report on Year 2 (FY 17/18) Final FY17/18 data upload to CEDEN	March 2019
Draft Data Report on Year 3 (FY 18/19) Provisional FY18/19 dataset for review by TAC	December 2019*
Final Data Report on Year 3 (FY 18/19) Final FY18/19 dataset upload to CEDEN	March 2020*

*The dates for these deliverables may be moved up, and only include partial year data, in order to provide timely information to inform the revision of the Central Valley Mercury TMDL.

Budget

	Actual	Actual	Old Plan	Proposed: 10 water events	Proposed: 9 water events	Selected: 8 water events	Planned	Planned
Fiscal Year	2016/17	2017/18	2018/19	2018/19	2018/19	2018/19	2019/20	2020/21
Fish Sampling Year	2016	2017	2018	2018	2018	2018	2019	2020
Fish								
Bass Monitoring at Six Sites: Sampling and Analysis	$45,344	$51,804	$53,358	$53,358	$53,358	$53,358	$54,959	$56,608
1 Site Add on				$7,521	$7,521	$7,521	$7,747	$7,979
MLML In-Kind	($8,262)	($5,100)	($5,100)	($5,100)	($5,100)	($5,100)	($5,100)	($5,100)
Water								
Water Monitoring at **Five** Sites, Quarterly: Sampling and Analysis	$65,310							
MLML In-Kind	($12,392)							
Water Monitoring at **Six** Sites, 8 months: Sampling and Analysis		$152,952	$157,541	$154,703	$154,703	$154,703	$159,344	$164,124
Water 2 site 8 month add on				$51,568	$51,568	$51,568	$53,115	$54,708
Water, 2 winter event, 8 sites				$51,568	$25,784	$0	$53,115	$54,708
MLML In-Kind		($16,700)	($16,700)	($24,900)	($22,410)	($19,920)	($24,900)	($24,900)
Sediment								
Sediment Monitoring at Six Sites, Quarterly: Sampling and Analysis		$29,260	$30,138	$0	$0	$0	$0	$0
MLML In-Kind		($3,200)	($3,200)	$0	$0	$0	$0	$0
Data Management, Oversight, Reporting								
SFEI Data Mgmt and QA Review	$15,000	$19,545	$20,131	$29,930	$29,930	$29,930	$30,828	$31,753
SFEI Oversight and Coordination	$3,000	$5,000	$5,150	$5,150	$5,150	$5,150	$5,305	$5,464
Interpretive Report							$20,000	
Total	$128,654	$258,561	$266,318	$353,798	$328,014	$302,230	$384,412	$375,345
MLML In-Kind	($20,654)	($25,000)	($25,000)	($30,000)	($27,510)	($25,020)	($30,000)	($30,000)
Total Cost to Delta RMP	$108,000	$233,561	$241,318	$323,798	$300,504	$277,210	$354,412	$345,345

Table 1. Sampling schedule for Delta RMP mercury monitoring. The March-October period used for the linkage analysis in the TMDL is indicated in bold font and with a gray background.

Year →	2016						2017												2018												2019												2020					
Fiscal Yr →	FY 16/17												FY17/18												FY18/19												FY19/20											
Month →	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
Monitoring element (# of sites sampled)																																																
Fish		*6*												*6*													*7*											*7*										
Water		*5*			*5*			*5*		*5*						*6*			*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*					*8*	*8*	*8*	*8*	*8*	*8*	*8*	*8*			*8*	*8*	*8*	*8*	*8*	*8*
Sediment																*6*			*6*			*6*		*6*																								

Table 2. Sampling frequency for the first two years of Delta RMP mercury monitoring, and planned and desired frequency in the next two years.

	Fish			Water			Sediment		
	Events	Sites	# Samples	Events	Sites	# Samples	Events	Sites	# Samples
FY16/17	1	6	6	4	5	20	-	-	-
FY17/18	1	6	6	7	6 - 8	54	4	6	24
FY18/19	1	7	7	8	8	64	-	-	-
FY19/20	1	7	7	10	8	80	-	-	-

Figure 1. *Planned sampling sites for methylmercury in FY18/19.*

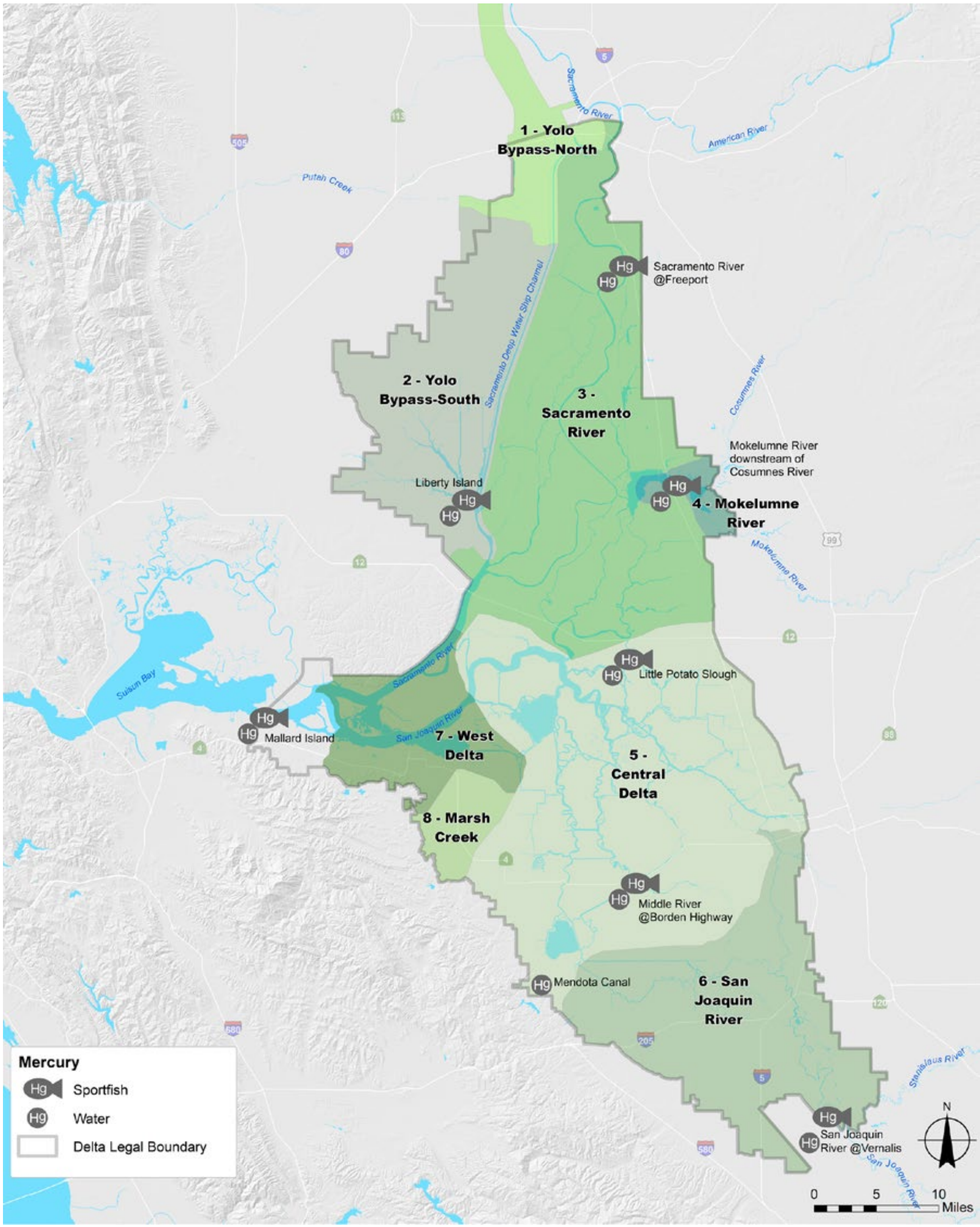


Figure 2. Long-term time series of mean mercury (ppm wet weight) in black bass for Delta RMP stations and nearby stations sampled historically. Details on following page.

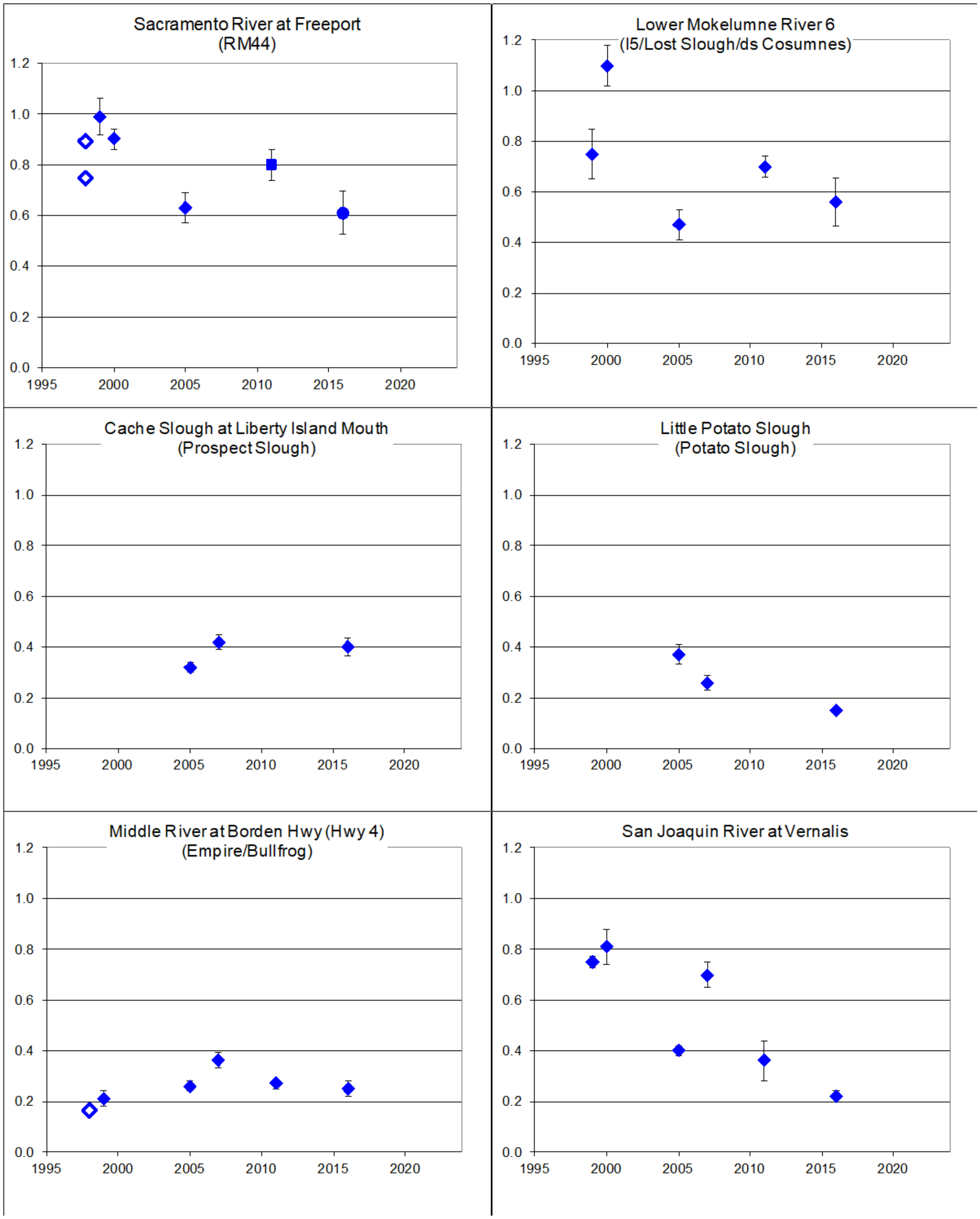


Figure 2 Details

Points generally show 350 mm length-adjusted means (exceptions to this noted in plot details below) and error bars indicate two times the standard error. Filled symbols indicate 350 mm length-adjusted means, hollow symbols indicate individual composite samples or arithmetic means when the station did not have a significant length:mercury correlation. Diamonds indicate largemouth bass; squares are spotted bass; circles are smallmouth bass. Data sources: Delta RMP - 2016; the Surface Water Ambient Monitoring Program (Davis et al. 2013) - 2011; the Fish Mercury Project (Melwani et al. 2009) - 2005-2007; the CALFED Mercury Project (Davis et al. 2003) - 1999-2000; the Delta Fish Study (Davis et al. 2000) - 1998; and the Sacramento River Watershed Program (2002) - 1998.

Sacramento River at Freeport
Stations - Freeport: 2016; RM44: All other years
Statistics - Individual composite results: 1998; 350 mm length adjusted mean: all other years

Lower Mokelumne River 6
Stations - Lower Mokelumne River 6: 2016; Mokelumne River near I-5: 2011; Lost Slough: 2005; Mokelumne River downstream of the Cosumnes River: 1999, 2000

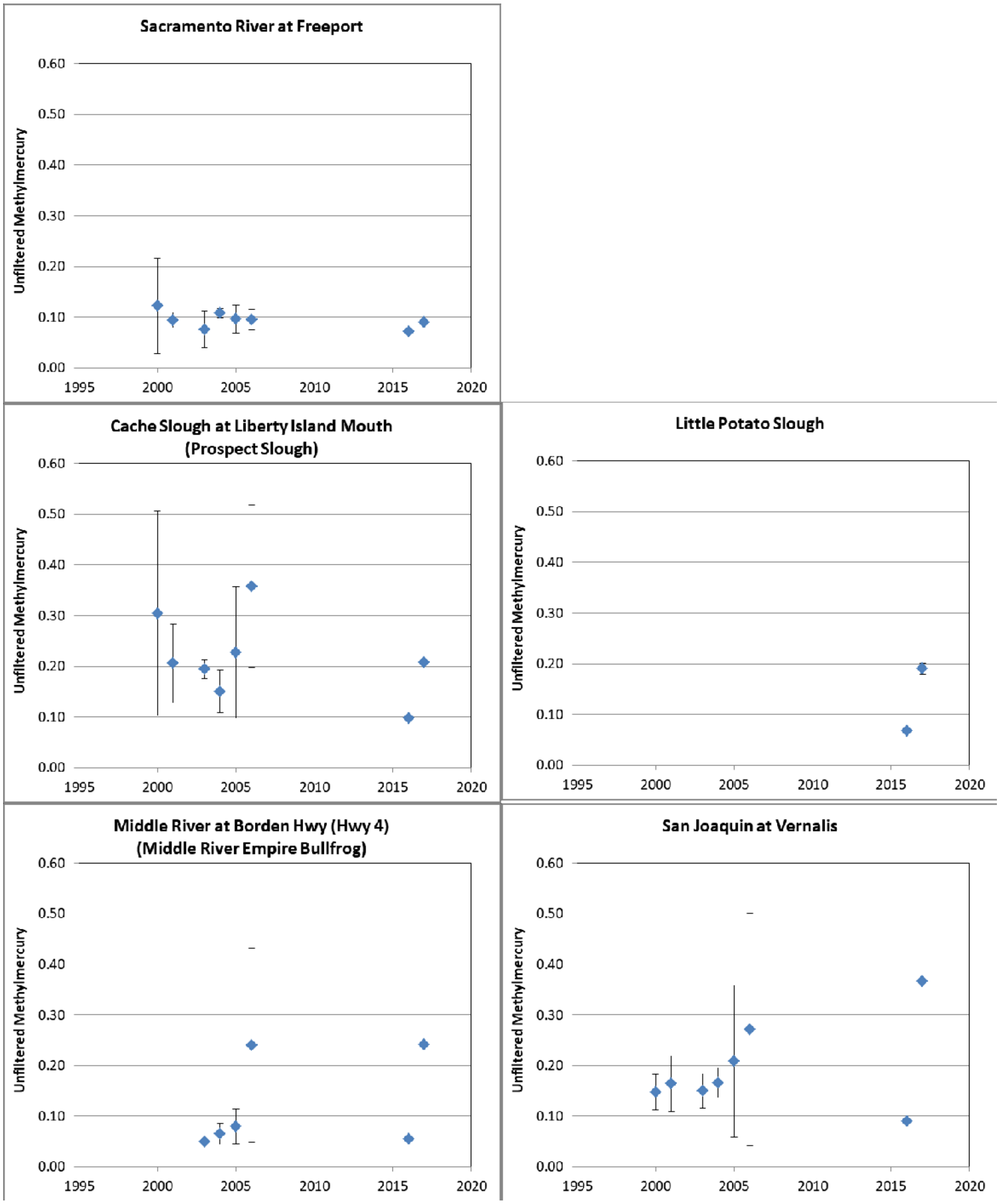
Cache Slough at Liberty Island Mouth
Stations - Cache Slough at Liberty Island Mouth: 2016; Prospect Slough: 2005, 2007

Little Potato Slough
Stations - Little Potato Slough: 2016; Potato Slough (aka San Joaquin River at Potato Slough): 2005, 2007

Middle River at Borden Hwy (Hwy 4)
Stations - Middle River at Borden Hwy (Hwy 4): 2016; Middle River near Empire Cut: 2011; Middle River at Bullfrog: 1998, 1999, 2007; Middle River at HWY 4: 2005
Statistics - Individual composite result: 1998; 350 mm length adjusted mean: all other years

San Joaquin River at Vernalis
Stations - Same station all years

Figure 3. Annual mean aqueous unfiltered methylmercury concentration at each Delta RMP monitoring station sampled from August 2016 through April 2017. Plots based on March-October data.



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DiGiorgio, Carol, Helen Amos, Jamie Anderson, Maninder Bahia, Cody Beals, Don Beals, David Bosworth, et al. "Creation of Mercury Models for the Delta and Yolo Bypass: Linking Modeling and Delta Regulatory Decisions." Sacramento, California, 2016. http://scienceconf2016.deltacouncil.ca.gov/content/creation-mercury-models-delta-and-yolo-bypass-linking-modeling-and-delta-regulatory.

Wood, Michelle L., Chris G. Foe, Janis Cooke, and Stephen J. Louie. "Sacramento – San Joaquin Delta Estuary TMDL for Methylmercury: Staff Report." Sacramento, California: Central Valley Regional Water Quality Control Board, 2010. http://www.waterboards.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/delta_hg/april_2010_hg_tmdl_hearing/apr2010_tmdl_staffrpt_final.pdf.

Attachment C Pesticides and Aquatic Toxicity Monitoring

Delta RMP Special Study Description for FY18/19 Workplan

Aquatic Toxicity and Current Use Pesticides Monitoring Using a Rotating Basin Probabilistic Design, Water Year 2019

Summary

The Delta RMP Steering Committee elected to fund the hybrid option (Option B) described in the monitoring proposal on the following pages. Funding was approved for Year 1 of the 5-year study.

Project Cost to the Delta RMP: **$211,578**

In-Kind Contributions:

State Water Resources Control Board, Surface Water Ambient Monitoring Program (SWAMP)	$328,040
U.S. Geological Survey	$13,704
US Army Corps of Engineers	$50,000
Total In-Kind Contributions	**$391,744**

Planned Deliverables:

- Amended QAPP, including detailed sampling and analysis plan
  - Draft Sept 2018
  - Final Oct 2018
- Year- end monitoring reports by USGS and AHPL
  - Draft: Nov 30, 2019
  - Final: Mar 31, 2020
- QA Officer Memo, dataset
  - Draft memo and dataset: Mar 31, 2020
  - Final memo and data uploaded to CEDEN: June 30, 2020

Scope Amendment

In approving the proposed workplan for pesticides and toxicity monitoring, the Steering Committee (at its meeting on July 17, 2018), specified that certain elements should be addressed as the program finalizes the Quality Assurance Program Plan prior to beginning monitoring. These required elements are described in a memo (dated July 17, 2018) by Regional San's SC member describing topics they wished to see addressed during QAPP development. The text of the memo is included below as an amendment to the scope of work.

Memo

To: Delta RMP Steering Committee

From: Rebecca Franklin, SC member, Regional San

Date: July 17, 2018

Re: QAPP topics for inclusion in: Aquatic Toxicity and Current Use Pesticides Monitoring Using a Rotating Basin Probabilistic Design, Water Year 2019 Work Group Discussions (Proposal; dated 7/3/18 for Delta RMP SC review)

The current draft Delta RMP Current Use Pesticide 2018-19 Monitoring Proposal identifies three topics that are not sufficiently described in the monitoring plan and will be discussed during QAPP development (Section: QAPP Modifications Needed; pages 33-34). Each of the three information gaps identified in the monitoring proposal are important and each will require effort to define and describe. Additional topics also need to be addressed in the QAPP so that data evaluation procedures are clear. These additional topics are listed below in blue as an addition to the three topics currently outlined on page 34 of the draft CUP Monitoring Proposal.

Topics to be addressed during QAPP development:

1) Sample location selection and pool of possible locations
2) Additional EC-based control and data interpretation protocols for Ceriodaphnia dubia toxicity tests
    a) Criteria for comparing samples with secondary controls – The Delta RMP should be able to develop program-specific data evaluation procedures to understand and agree on how data evaluation informs the program's goals.
    b) Criteria for evaluating data when secondary controls do not meet test acceptability criteria (TAC) - Delta RMP should understand and agree on how data evaluation informs the program goals.
    c) Criteria for evaluating data when secondary controls are significantly different (or not significantly different) from primary controls – The Delta RMP should develop program-specific data evaluation procedures to understand and agree on how data evaluation informs the program goals.
3) Toxicity test methods for Chironomus dilutes
4) Test termination criteria for Ceriodaphnia dubia - Testing should be complete when 60% or more of surviving control females have produced three broods of offspring as defined in EPA (2002) guidance.
5) Reporting and interpreting reference toxicity data - The reference toxicity warning and control limits should be calculated in accordance with EPA (2002) guidance.

6) Define a weight-of-evidence process to trigger retesting of toxicity samples or invalidate test results - Rather than developing hard rules, it may be best for the Delta RMP to identify triggers for the lab to notify the TAC (toxicity work group) when there are indications of potential concerns. Together, the lab and TAC can determine a path forward, rather than the lab making the decision alone. This is the same as the current approach used for go/no-go decisions for toxicity identification evaluations (TIEs).

Revised Detailed Budget

The project budget has been revised to take into account a $50,000 in-kind contribution by the US Army Corps of Engineers to directly fund work by the USGS. However, this contribution has only offset $44,356 in expenses by the Delta RMP due to federal contracting rules. The proposed workplan included a planned $19,344 cost share by the USGS. Under the revised budget, the USGS cost share will be $13,700, or $5,644 lower than we had originally anticipated. A more detailed explanation follows.

The Joint Funding Agreement between ASC and the USGS for pesticides monitoring includes an in-kind contribution on the part of USGS, in the form of a 10% federal cost share on labor and travel expenses. However, when USGS receives funding from another federal agency, there is no cost share available. In addition, the overhead rate on the Corps funds is a fraction of a percent higher than for USGS' funding agreement with ASC. As a result of these changes, the USGS Pesticide Fate Research Group (PFRG) gave us a revised budget for FY18/19 pesticide sampling. The total project cost is the same, however, the USGS cost share is lower than before:

	Old cost estimate	**Revised amount in joint funding agreement**
Delta RMP funding (via ASC)	$199,873	$155,517
USGS cost share	*$19,344*	*$13,700*
Army Corps contribution	-	$50,000
Total Project Cost	**$219,217**	**$219,217**

As noted, the total cost of the pesticides monitoring project is the same. The revised funding arrangement will provide the exact same amount of personnel hours, supplies, analytical costs, etc. as were originally planned. However, while the Delta RMP is **gaining** a $50,000 in-kind contribution from the Corps, in a sense we are **losing** an anticipated $5,644 in-kind contribution from the USGS. This can be thought of as a "cost of doing business." We still benefit greatly from this new indirect contribution to the program by the Army Corps.

A revised budget showing planned expenses is shown in the table on the following page.

Table Revised budget for approved FY18/19 Delta RMP monitoring of current-use pesticides and toxicity

(Revised budget to account for $50,000 direct contribution by the US Army Corps of Engineers.)

Contractor	Item	Number	Unit Cost	Total Cost
USGS	Field sample collection and lab analysis			
	Project oversight and reporting	1		$19,350
	Sample collection, labor	48		$19,673
	Sample collection, supplies	48		$7,445
	GC/MS Analyses	48		$45,233
	LC/MS/MS Analyses	48		$59,804
	NWQL Analyses	48		$11,025
	Reports	1		$6,691
	USGS Cost share			–$13,704
				$155,517
AHPL	Toxicity Reporting			
	Provisional Data			
	A) SWAMP Toxicity Transformers (no charge)	6	0	$0
	B) Bench Sheet Copies	6	$500	$3,000
	C) Reference Toxicant Control Charts	6	$875	$5,250
	D) Corrective Actions Table	6	$100	$600
	Attend meetings and present preliminary results	4	$800	$3,200
	Indirect costs (University mandated 25%)			$3,013
				$15,063
ASC	Data Management and Quality Assurance	(hours)	(rate)	
	DS Project Management and Coordination	70	$115	$6,900
	Data Receipt and Data Management	193	$105	$16,485
	Data Validation	88	$152	$7,904
	Data Storage and Release	46	$100	$4,600
	Toxicity data QA Summary	10	$152	$1,520
	10% contingency			$3,589
				$40,998
Total Cost to the Delta RMP…………				$211,578

Delta RMP Special Study Proposal

Aquatic Toxicity and Current Use Pesticides Monitoring Using a Rotating Basin Probabilistic Design, Water Year 2019

Executive Summary

Estimated Cost:

Delta RMP Funds: $248,352 or $255,933 (depending on monitoring design chosen)

SWAMP Funds (in-kind contribution): $311,120

USGS In-kind contribution: $18,022

Oversight Group: Delta RMP Pesticides Subcommittee

Proposed by: SFEI-ASC, USGS

This proposal requests funding from the Delta RMP Steering Committee for Year 1 of a 4- to 5-year study of current-use pesticides and aquatic toxicity in the Sacramento-San Joaquin Delta. Two options are proposed: 1) a rotating basin monitoring design and 2) a hybrid design that adds monitoring at 2 fixed sites selected based on previous monitoring history. Both options include a statistical survey of subregions of the Delta and include analysis of the same constituents. Year 1 monitoring would begin in October 2018 and continue through September 2019 (2019 Water Year); years 2–4 would continue to be based on a water year. A key to the success of a status and trends monitoring program is that it be sustained over a long time. This proposal describes a 3 to 4 year monitoring program covering the Delta. During year 4, an interpretive report is planned, from which lessons may be drawn to adaptively manage and improve future monitoring.

Under this "rotating basin" monitoring design, the Delta is split into 6 subregions (established by prior analytical work by the Delta RMP) and 2 subregions are monitored each year. All 6 subregions are monitored over a 3-year cycle. Within each subregion, sampling points are randomly selected using the Generalized Random-Tessellation Stratified (GRTS) method. Subregions will be further stratified or divided into two water body types, representing 1) large river channels and open water lakes, and 2) smaller, shallower streams and sloughs. An advantage of this random or "probabilistic" design is that it allows the use of standard statistical methods to make inferences about Delta waterways as a whole, and to calculate the uncertainty for estimates in terms of confidence intervals. A key output of the study will be to determine what percent of Delta waterways exhibit toxicity to aquatic organisms or have concentrations of pesticides that exceed a water quality threshold or aquatic life benchmark.

During Year 1 of the study, 48 water samples will be collected by boat from 2 Delta subregions by field crews from the USGS California Water Science Center in Sacramento. Samples will be analyzed for a suite of 174 Current Use Pesticides (CUP) by the USGS Organic Chemistry Research Laboratory (OCRL). Compounds include fungicides, herbicides, insecticides, and their degradation products. In addition, crews will measure field parameters (water temperature, pH, conductivity, dissolved oxygen, turbidity), and document conditions at the field site. The USGS National Water Quality Laboratory will analyze samples for copper and ancillary parameters (total nitrogen, total particulate carbon, particulate organic carbon, and dissolved organic carbon).

The Aquatic Health Program Laboratory at UC Davis will analyze the toxicity of water samples for a suite of test organisms based on EPA (2002, 2000) and SWAMP (2008) methods:

- *Ceriodaphnia dubia*, a daphnid or water flea (survival, reproduction) – sensitive to organophosphate pesticides
- *Hyalella azteca*¸ an aquatic invertebrate (survival) – sensitive to pyrethroids
- *Selenastrum capricornutum* (also known as *Raphidocelis subcapitata*), a single-celled algae (growth) – sensitive to herbicides
- *Chironomus dilutus*, midge larvae (formerly *Chironomus tentans)* - sensitive to fipronil and more sensitive in chronic exposures to imidacloprid than *C. dubia.*
- *Pimephales promelas* (growth, survival) – chronic and acute effects on whole organism growth and survival

If toxicity exceeding a certain threshold is found in a water sample, we may instruct the lab to conduct follow-up investigations to determine the cause of toxicity, by performing a Toxicity Identification Evaluation (TIE). As in past years of monitoring, the discussion of whether to conduct a TIE will be triggered when significant toxicity is observed exceeding a pre-determined threshold, and decided upon by a subcommittee of stakeholders and technical experts.

A hybrid option (Option B) is included in this proposal. It reduces the number of probabilistic samples collected each year in order to continue monitoring at two fixed sites (Ulatis Creek at Brown Road and San Joaquin River at Buckley Cove) where aquatic toxicity has been observed in the past. This "hybrid" option includes the capability of detecting trends at these two sites over a longer period of continuous data and may provide additional opportunities to test for association s between pesticides and toxicity at these locations. However, under Option B we would collect fewer random samples in each subregion each year, requiring one extra year to obtain the number of samples estimated for the desired statistical power of the study.

This proposal was developed with the collaboration of the Delta RMP Pesticides Subcommittee and with the input of a consulting statistician. During the proposal development process, we sought to follow the recommendations of the 2016 Independent Panel Review (Raimondi et al. 2016). The key recommendations were to: (1) engage the services of a professional environmental statistician, (2) consider a random sampling to expand beyond monitoring at fixed sites only and expand capability to draw inferences about more areas of the Delta, and (3) clearly define quantities to be observed or estimated from measurements. We have responded to the first two recommendations during the planning of this monitoring design by engaging an environmental statistician with experience in randomized sampling design to analyze the first two years of Delta RMP pesticides and toxicity data, perform power analyses, and advise us on the monitoring design. A report by our consulting statistician is provided in Appendix 3. We responded to (3) by following the EPA's Data Quality Objectives (DQO) process, stating *a priori* the information to be collected, the analytical approach to be used to evaluate data, and tolerable limits on decision errors. More information on this is provided in the section Data Analysis and Presentation on page 35.

There are tradeoffs involved in designing a monitoring program due to budget and practical constraints. The strengths and limitations of the proposed monitoring designs are listed in more detail on page 24.

The Steering Committee is being asked to commit funding for the first year of this 4-year plan. However, this proposal is not intended to lock us into an inflexible program. The program should be open to "adaptively manage" and make changes to the monitoring design. For instance, we have recently hired a contractor to analyze the data on pesticides and toxicity from the first two years of monitoring from 2015 to 2017. We may wish to make changes to the monitoring design based on the results of data analysis and interpretation, and as our knowledge and priorities change over time.

Contents

Tables

Figures

Acronyms and Abbreviations

AHPL	Aquatic Health Program Laboratory at UC Davis
ASC	Aquatic Science Center
BLM	biotic ligand model
BPA	Basin Plan Amendment
CAWSC	USGS California Water Science Center
CC	chief chemist
CDF	cumulative distribution function
CEDEN	California Environmental Data Exchange Network
CUP	Current Use Pesticides
CVRWQCB	Central Valley Regional Water Quality Control Board
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DM	Database manager
DMS	Data management staff
DQO	Data quality objectives
DWR	Department of Water Resources
EC	electrical conductivity
EPA	Environmental Protection Agency
FY	Fiscal year (July 1 – June 30)
GC/MS	Gas chromatography/mass spectrometry
GIS	Geographic Information System
LC50	Lethal concentration (that kills 50% of the test organisms during the observation period)
GRTS	Generalized Random-Tessellation Stratified (sampling method)
LC/MS	Liquid chromatography/mass spectrometry
MDL	Method detection limit
MQO	Measurement quality objective
NA	Not applicable
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWIS	USGS National Water Information System
NWQL	National Water Quality Laboratory
NWQMC	National Water Quality Monitoring Council
OCRL	Organic Chemistry Research Laboratory
OFR	USGS Open File Report
OPP	USEPA Office of Pesticides Programs
PD	Project director
PTI	Pesticide Toxicity Index
QA	Quality Assurance
QAO	Quality assurance officer

QAPP	Quality Assurance Program Plan
QC	Quality control
RL	Reporting limit
RMA	Resource Management Associates
RMP	Regional Monitoring Program
S&T	Status & Trends
SFEI	San Francisco Estuary Institute
SJR	San Joaquin River
SWAMP	Surface Water Ambient Monitoring Program
TAC	Technical Advisory Committee
TIE	Toxicity identification evaluation
TMDL	Total Maximum Daily Load
USGS	U.S. Geological Survey

Background and Motivation

A better understanding of the effects of contaminants in the apparent decline of Delta ecosystems is a priority for regulators and stakeholders. Pesticide use in the Delta and Central Valley generally is one of the potential drivers of these effects. Constantly changing pesticide use presents a challenge for environmental scientists, resource managers, and policy makers trying to understand whether these contaminants are impacting aquatic systems and if so, which pesticides appear to be the biggest problem. Less than half of the pesticides currently applied in the Central Valley are routinely analyzed in monitoring studies and new pesticides are continually being registered for use. Therefore, baseline monitoring of ambient surface water for both aquatic toxicity and a broad list of current use pesticides is needed to understand whether current use pesticides contribute to observed toxicity in the Delta.

Regulatory Drivers

The proposed monitoring is intended to provide useful information to state and federal water quality regulators. Important regulatory drivers are described below.

Water Quality Control Plan for the Central Valley Basin (Basin Plan)

According to the State Water Board, the Basin Plan is "the Board's master water quality control planning document. It designates beneficial uses and water quality objectives for waters of the State, including surface waters and groundwater. It also includes programs of implementation to achieve water quality objectives."

The Central Valley Basin Plans states that, "in addition to numerical water quality objectives for toxicity, the Basin Plan contains a narrative water quality objective that requires all surface waters to '...be maintained free of toxic substances in concentrations that are toxic to or that produce detrimental physiological responses to human, plant, animal, and aquatic life.' To check for compliance with this objective, the Regional Water Board initiated a biotoxicity monitoring program to assess toxic impacts from point and nonpoint sources in FY 86-87" (CVRWQCB 2016, IV-32.08). The plan states that the Regional Board "will continue to impose toxicity testing monitoring requirements in National Pollutant Discharge Elimination System (NPDES) permits. The focus of ambient toxicity testing will continue to be the Delta and major tributaries." In other words, the Board is interested in verifying that there are "no toxics in toxic amounts" in waterways, and will continue to require aquatic toxicity testing as a key means of making this determination.

Organophosphate TMDL

In 2006, the Central Valley Water Board identified Delta waterways as impaired under the federal Clean Water Act Section 303(d) due to elevated concentrations of the organophosphate pesticides diazinon and chlorpyrifos and created a plan for their allowable discharge to the Delta referred to as the Total Maximum Daily Load (TMDL). Under this plan (CVRWQCB 2006), the board put in place a number of new rules and requirements. One of these stated that new discharge permits (or WDRs) for runoff from fields and orchards draining to Delta Waterways must contain monitoring to meet a number of goals, the most relevant being:

- Determine attainment of the diazinon and chlorpyrifos water quality objectives and Load Allocations (additivity target).
- Determine whether alternatives to diazinon and chlorpyrifos are causing surface water quality impacts.
- Determine whether the discharge causes or contributes to a toxicity impairment due to additive or synergistic effects of multiple pollutants

In addition are nearly identical requirements for agricultural dischargers to the Sacramento and San Joaquin River under those TMDLs, respectively (Daniel McClure, personal communication).

Control Program for Diazinon and Chlorpyrifos

In 2014, the Central Valley Water Board published an additional amendment to the Basin Plan containing a control program for discharges of diazinon and chlorpyrifos (CVRWQCB 2014). The control plan created new pollution control requirements for waterways designated as supporting both warm and cold freshwater habitats. Under these requirements, agricultural, municipal stormwater, and wastewater dischargers in the Sac -SJR basins below major reservoirs are required to monitor in order to:

- Determine compliance with established water quality objectives applicable to diazinon and/or chlorpyrifos.
- Determine whether alternatives to diazinon and/or chlorpyrifos are being discharged at concentrations which have the potential to cause or contribute to exceedances of applicable water quality objectives.

In addition, agricultural dischargers are also required to monitor water quality in order to:

- Determine whether the discharge causes or contributes to a toxicity impairment due to additive or synergistic effects of multiple pollutants

Pyrethroids Basin Plan Amendment

In 2017, the regional board determined that more than a dozen waterways are impaired due to elevated concentrations of pyrethroid pesticides under Clean Water Act section 303(d). In response, the regional board adopted a Basin Plan Amendment (CVRWQCB 2017) which includes a pyrethroid pesticide control program for the Sacramento and San Joaquin River Basins. This Basin Plan Amendment was adopted by the regional board in June 2017 and it is expected to be fully approved by Stater Water Board, the Office of Administrative Law, and EPA by the end of 2018.

The amendment contains requirements for monitoring of pyrethroids, pyrethroid alternatives, and aquatic toxicity to the invertebrate *Hyalella* in discharges and/or receiving water in order to:

- Determine If the pyrethroid concentration goals are being attained through monitoring pyrethroids either the discharge (POTWs) or discharge or receiving water (MS4s and Ag dischargers)
- Determine whether pyrethroid pesticides are causing or contributing to exceedances of the narrative water quality objective for toxicity – through toxicity testing with Hyalella in water column of receiving waters (POTWs) or receiving waters water column and bed sediments (Ag and MS4s)

This monitoring must be completed two years from the effective date of the Basin Plan Amendment (BPA), expected December 2018. In the long term after that two-year period, dischargers will also be required to monitor for alternative insecticides that could be having water quality impacts.

Objectives of the Delta RMP Current Use Pesticides Monitoring Program

The overall objectives of the Delta Regional Monitoring Program's (Delta RMP's) Current Use Pesticide (CUP) monitoring program are to collect ambient surface water samples to answer the Program's Management and Assessment Questions (Table 1). The management and assessment questions are broad and the Delta is large, so addressing them will require a correspondingly large effort over the course of several years. The current proposed study design was developed to make the best use of available funding to answer the highest priority Management and Assessment Questions in an initial effort to characterize status and trends of pesticide concentrations and toxicity in the Delta.

Proposed Delta RMP CUP monitoring includes the collection of samples for aquatic toxicity testing and analyzing pesticide concentrations in water samples at multiple randomly-chosen sampling locations within subregions of the Delta. One or more of these areas would be assessed each year over the rotation cycle.

Applicable Management and Assessment Questions

Table 1 shows the Delta RMP Management and Assessment Questions that this study can help answer. The table also shows the objectives of the project and examples of how the information collected by the project can be used by water managers and water quality regulators.

Table 1 Delta Regional Monitoring Program Management and Assessment Questions

Relevant Management and Assessment Questions	Study Objectives	Example Information Application
Management Question Is water quality currently, or trending towards adversely affecting beneficial uses of the Delta? **Assessment Questions** S&T 1 - To what extent do current use pesticides contribute to observed toxicity in the Delta? S&T 1.1 - If samples are toxic, do detected pesticides explain the toxicity? S&T 1.2 - What are the spatial and temporal extent of lethal and sublethal aquatic and sediment toxicity observed in the Delta? S&T 2 - What are the spatial/temporal distributions of concentrations of currently used pesticides identified as possible causes of observed toxicity?	Collect water samples from a variety of locations across Delta subregions and analyze them for a broad suite of current use pesticides and for toxicity to aquatic organisms. Test whether pesticides in ambient water samples exceed aquatic life benchmarks. Test for the co-occurrence of pesticides and observed aquatic toxicity.	The Delta RMP can use this information to determine what percentage of Delta waters exhibit toxicity to aquatic organisms or have concentrations of pesticides that exceed thresholds. State water quality regulators may use this information to help evaluate if waterways should be classified as impaired under section 303(d) of the Clean Water Act. Regulators will be able to evaluate particular stream segments and parameters for signs of impairment, and, after several years of monitoring, may be able to track changes in impairment over time. If certain compounds are found to be having adverse impacts on aquatic environment that prevent the obtainment of beneficial uses, regulators may require the development of a management plan to prevent or mitigate pesticide contamination of waterways, or when warranted, adopt restrictions to further protect surface water from contamination.

Technical Approach

The Delta RMP will collect ambient surface water samples to be analyzed for pesticide concentrations and toxicity to established aquatic test species during multiple sampling events in the Sacramento-San Joaquin Delta from October 2018 to September 2019. The sampling program is based on a "rotating basin" monitoring design. This design is widely used to assess water bodies on a large geographic scale, repeated at regular intervals, while allowing resources to be focused on smaller geographic areas in any given year (NWQMC 2017). To implement the design, the resource (in our case, Delta waterways) is divided into smaller geographic areas, referred to in this proposal as "subregions," and one or more of these areas is assessed each year over the rotation cycle. A rotation cycle is typically five or more years in length. In our case, we have divided the Delta into 6 subregions, and propose to monitor 2 subregions per year over a cycle of 3 or 4 years.

The rotating basin design allows us to assess pesticide and toxicity conditions in individual subregions of the Delta and in the Delta as a whole. The goal is to collect a minimum of 24 samples from 24 different locations in each subregion. This will allow for an assessment of the condition of the subregions over a 3- to 4-year period. Due to the constraints of the budget is it not possible to monitor all subregions within a single year. The proposed monitoring design allows for spatial representation and increases the statistical power to be able to detect differences among the subregions.

Further stratifying regions by water body type ensures that the entire Delta is adequately represented in the sampling design and that we can draw inferences about different types of water bodies, such as large fast-flowing river channels to smaller creeks and sloughs. More details on when and where we propose to monitor, and how the sampling locations will be chosen, are provided in the following section.

Adaptive management of the study design – The TAC has discussed whether it makes sense to commit to a multi-year project before the Pesticides and Toxicity interpretive report and analysis is complete. The TAC concluded that we should plan to "adaptively manage" and change our monitoring design based on the results of data gathering and interpretation. This is in fact, a key expected outcome of the interpretive report that is currently underway by Deltares; the scope of work for the study says that the analysis should "inform decisions about future monitoring for pesticides and toxicity in the Delta." Therefore, this proposal is not intended to lock us into an inflexible program. On the contrary, the program should remain open to make changes as our knowledge and priorities change over time.

Geographic and Temporal Scope

Delta Subregions

Samples will be collected from within the legal boundaries of the Delta. Previous efforts by both the Delta RMP and the Central Valley Regional Water Quality Control Board (CVRWQCB) have divided the Delta into roughly similar regions based on hydrology and management practices.

The Delta RMP has divided the Delta into 7 regions based on the contribution of source waters, as described in the 2018 report *Modeling to Assist Identification of Temporal and Spatial Data Gaps for Nutrient Monitoring* (Jabusch, Trowbridge, Heberger, and Guerin 2018). The CVRWQCB has also identified regions within the Legal Delta which it uses for the 303(d) list. The boundaries of the subregions are shown in Figure 1. Other monitoring efforts by the Delta RMP are utilizing the subregions identified in Jabusch et al. 2018 (Delta RMP subregions) including the nutrient monitoring design; therefore, this proposal includes assessing the subregions defined by this effort rather than the 303(d) waterways. The rotating basin monitoring design includes monitoring 6 of the 7 subregions shown in Figure 1, excluding the Suisun Bay subregion, which is outside of the Legal Delta. (Note that the numbers on this figure are only placeholders and are not intended to dictate the order in which subregions are monitored.)

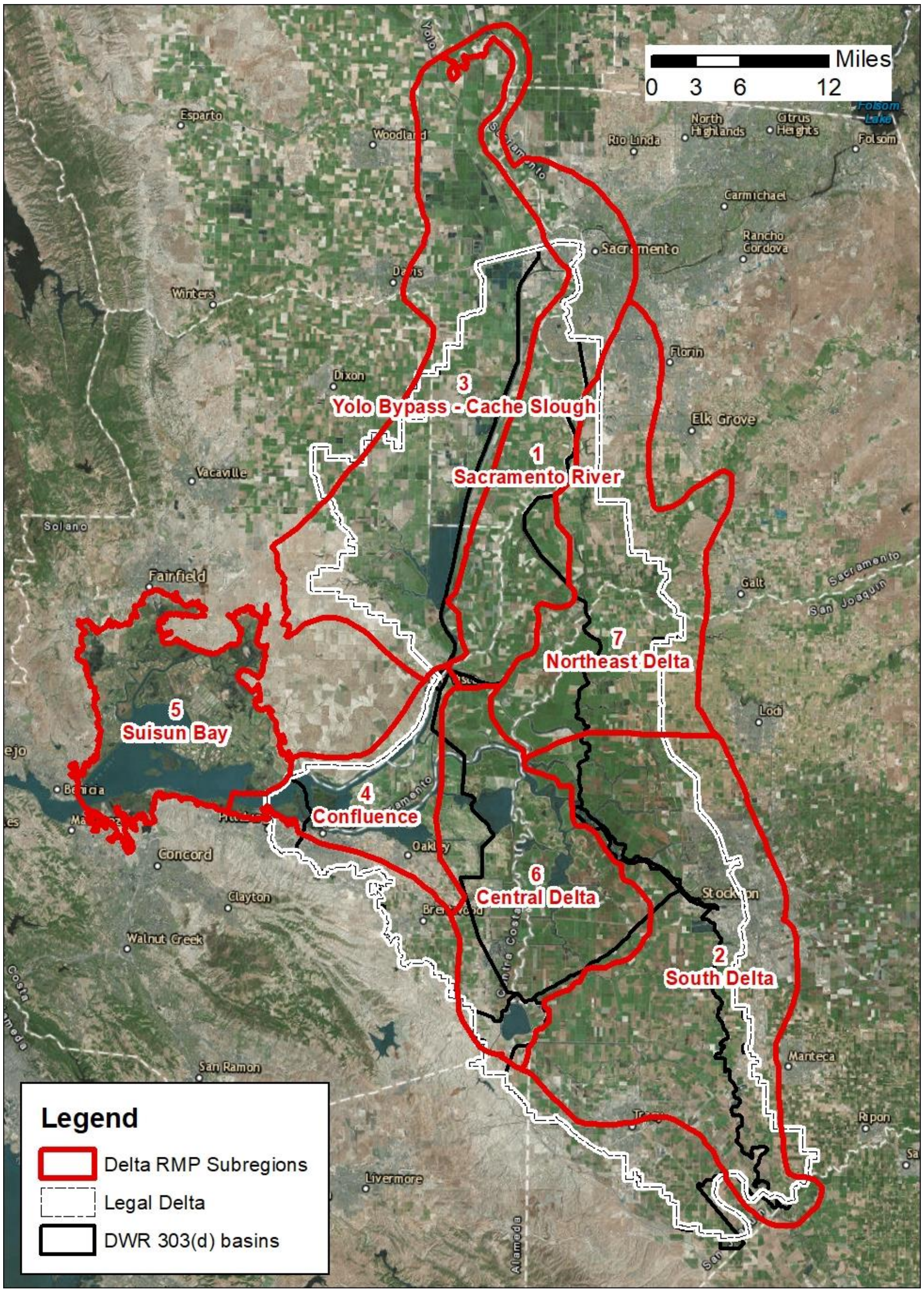

Figure 1 Map of Delta RMP subregions

Temporal Scope

In this proposal, we are requesting the first year of funding for a proposed monitoring design that will last for 4-5 years depending on the option selected. Year 1 of this effort would begin in October 2018 and end in September 2019.

We propose 6 sampling events during each water year. Samples will be collected over the course of 2 to 3 days at the following during times of interest (high agricultural and/or urban irrigation). Other sampling will occur during periods of high flow or following storms when pollutants are flushed from land surfaces into waterways via overland flow and drains. These events may include the fall "first flush," a second winter storm, and a period of high flow during spring runoff (snowmelt). Storm triggers are perhaps one of the most significant elements of stormwater sampling.

The specific timing will be planned in collaboration with the Delta RMP Pesticides Subcommittee and our science advisors and will be documented in detail in the Quality Assurance Program Plan (QAPP). This planning will occur from July to September of 2018, and the deliverable will be the detailed sampling and analysis plan included in the revised QAPP. Table 2 shows the sampling event triggers in the Delta RMP 2016 QAPP, which can be adapted or expanded upon for proposed monitoring program. Furthermore, special consideration may be needed in the event of a drought year. We will work with the Pesticides Subcommittee of the TAC to determine a course of action if the storm trigger conditions are not met by a particular date.

Table 2 Sampling event triggers in the Delta RMP 2016 QAPP, to be adapted for proposed monitoring program

Event	Sampling Triggers	Criteria	Notes
Wet			
1st seasonal flush (Water Year)	• Guidance plots project significant increase (~25%) in flow at four sites: lower Sacramento River, lower American River, San Joaquin River at Vernalis, and Mokelumne River.	• Preceded by $\geq$30 days dry weather (Sacramento R. stormwater criteria).	• *Sample events to hit all sites in 1 to 2 days.* • *When favorable storm conditions and runoff are forecast coordinate directly with AHP lab.* • *Alert AHPL 7 days in advance of upcoming storm for organism preparation and 2 days in advance about likelihood of adequate precipitation*
Significant winter storm	• Guidance plots project significant increase (~25%) at four sites: lower Sacramento River, lower American River,	• Minimum 2 weeks since 1st flush sample event.	• *If collect more than 1 event sample in the same month, do not sample in following month.*

Event	Sampling Triggers	Criteria	Notes
	San Joaquin River at Vernalis, and Mokelumne River.		• *When favorable storm conditions and runoff are forecast coordinate directly with AHP lab.* • *Alert AHPL 7 days in advance of upcoming storm for organism preparation and 2 days in advance about likelihood of adequate precipitation*
Dry			
Early Spring	• No triggers, can sample in a particular month (March-April).	• None	• *Meant to capture snowmelt but recognize significant impact of upstream dams.* • *Coordinate sampling schedule with AHP lab 7 or more days in advance.*
1st irrigation season sampling (late spring/ early summer)	• No triggers, can sample in a particular month (May-June).	• None	• *Meant to capture late winter and spring pesticide applications (post storms).* • *Account for planting/ pesticide application timing.* • *Coordinate sampling schedule with AHP lab 7 or more days in advance.*
2nd irrigation season sampling (late summer)	• No triggers, can sample a particular month (August).	• None	• *Meant to capture summer pesticide applications (rice, etc.).* • *Account for planting/ pesticide application timing.* • *Coordinate sampling schedule with AHP lab 7 or more days in advance.*

Monitoring Design

The two monitoring design options are presented in Table 3. The options involve collecting 48 ambient surface water samples under Option A, or 57 samples under Option B in Water Year 2019. Both monitoring design options would result in 30 samples from each of the 6 Delta subregions after 3 or 4 years of monitoring depending on the design selected. This will allow us to draw conclusions about water quality conditions across the Delta, as well as differences among the subregions.

There were several constraints on designing a pesticides monitoring program in 2018/19. Based on the available budget and laboratory costs, a maximum of around 60 samples can be collected and analyzed per year. Due to logistical constraints involving the toxicity testing laboratory, no more than 15 samples can be analyzed for planned toxicity tests per sampling event. This number is based on the proposed suite of test organisms, and is based on available bench space, refrigeration, labor to initiate tests, etc.

Option A, the "rotating basin" probabilistic monitoring design, is excellent for the purpose of understanding the spatial extent of toxicity and pesticide concentrations. In this instance, the "basins" are our 6 Delta subregions. The rotating basin approach will allow for enough samples in each subregion to characterize the variance of concentrations in the subregion. A weakness of the approach is that subregions will be sampled in different years under different weather conditions. Therefore, comparisons between subregions will be compromised. With Option A, after 3 years, we will have collected data for the whole Delta. Further, we will have collected 30 samples in each of the subregions, which allows us to make statistical comparisons between subregions with a reasonably small margin of error.

Under **Option B**, the "hybrid" design, we keep the rotating basin design but reduce the number of probabilistic samples in order to continue monitoring 6 times per year at two fixed sites. Both sites, Ulatis Creek at Brown Road and San Joaquin River at Buckley Cove, are locations where aquatic toxicity has been observed by Delta RMP monitoring in the past (Figure 2). For more information on the first year of Delta RMP pesticides monitoring, see recent reports by the USGS (De Parsia et al. 2018) and SFEI-ASC (Jabusch, Trowbridge, Heberger, Orlando, et al. 2018). This "hybrid" option includes the capability of detecting temporal trends at these two sites and an analysis of the correlation between pesticide concentrations and toxicity. By sampling at the same location repeatedly, we are holding more factors constant, which may provide additional opportunities to test for the association between pesticides and toxicity at these locations. However, because of the limited budget, there is a trade-off of collecting fewer random samples in each subregion each year, which means it will take us an additional year to reach the desired 30 samples in each subregion.

Table 3   Rotating Probabilistic Monitoring Design Options with/without 1 fixed site per subregion

Option	**Option A (Rotating Basin)**	**Option B (Hybrid)**
Number of random sample locations per subregion	24	24 in first region 12 in second subregion
Subregions evaluated per year	2	2
Number of repeated sample locations per subregion	0	0
Number of fixed sites sampling locations	0	2
Sampling events per year	6	6
Total samples per year	48	36 samples at random locations; 12 samples at 2 fixed sites; 48 samples total
Time (years) to collect 30 samples in all subregions covering the Delta	2 regions evaluated in any given year. 3 years to cover whole Delta with desired margin of error.	One subregion fully evaluated (n = 24) in any given year. Second subregion will be sampled at half the intensity (n=12) with sampling to be continued over two subsequent years to reach the desired number of samples. Based on the lower intensity of sampling, it will take 4 years rather than 3 in order to obtain 24 samples in each subregion and cover the whole Delta with the desired margin of error.

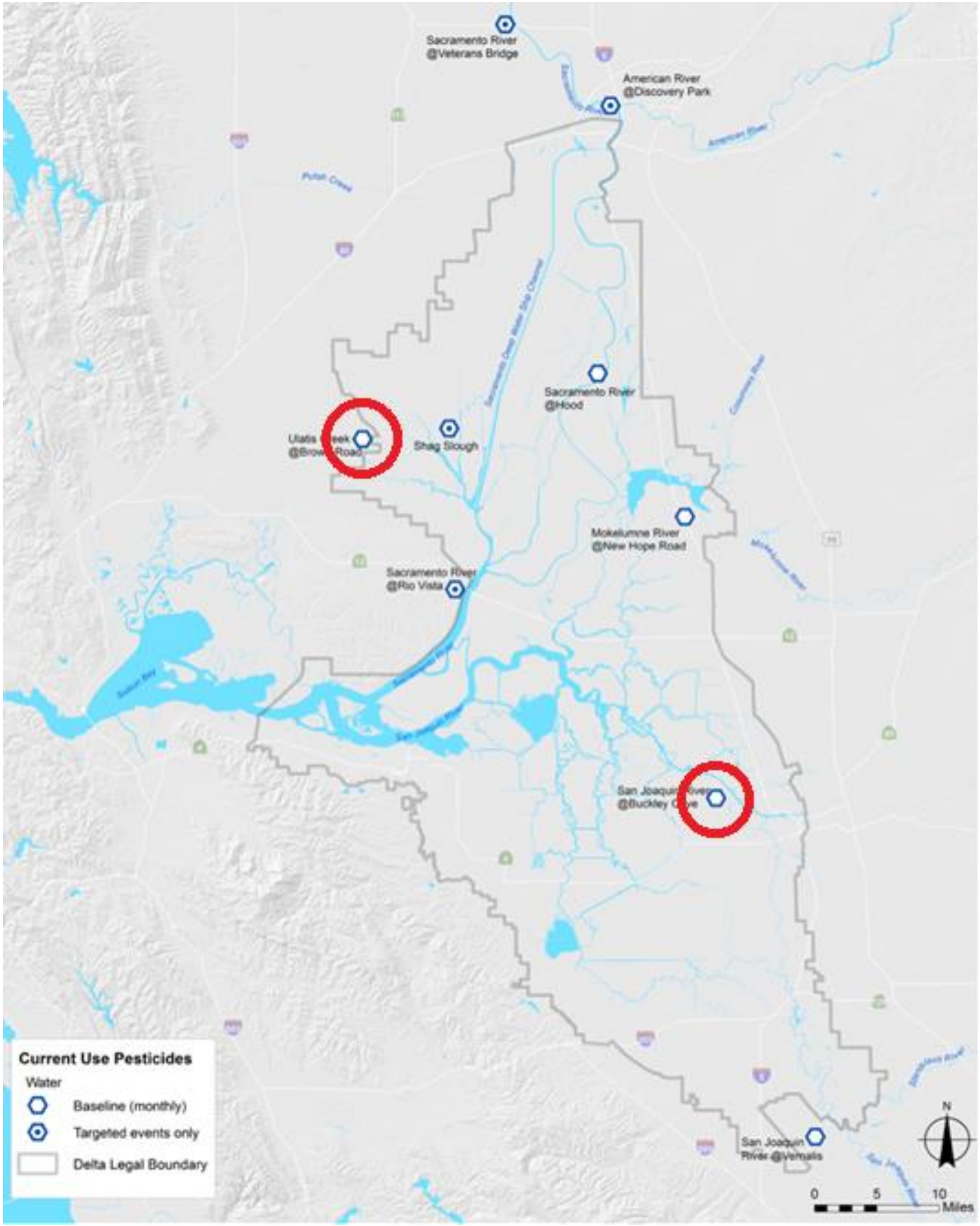

Figure 2 Map of Delta RMP integrator sites monitored 2015-2017, highlighting the two fixed stations where continued monitoring is proposed.

Table 4 shows a schedule of monitoring and deliverables for years 1 through 5 of the proposed monitoring designs. Under both options, sampling will be conducted in two out of six subregions each year. At the end of the 3-year cycle, we will analyze the collected data and determine whether it makes sense to continue the existing monitoring design or to reevaluate. Under Option B, we will continue monitoring into Year 4 in order to obtain our target of 30 samples in each of the 6 subregions.

In terms out reporting and deliverables, the Annual Field Sampling Report will document sample collection methods, target sampling sites, actual sampling sites, how many samples were collected, measurements made using field instruments, and any deviations from the QAPP for field sampling methods. After 3 years of data collection, we will have sampled the entire Delta. In Year 4, a Summary and Interpretive Report will be prepared. Under option B, this report would be prepared in Year 5. This interpretive report will answer the program's management and assessment questions to the extent possible. Namely, the analysis will determine whether, and to what extent, pesticides contribute to observed toxicity in the Delta. The report will show where and when pesticides and toxicity are observed, prioritize which pesticides should be monitored in the future, and describe gaps in current monitoring programs that limit answering other important management questions.

Table 4 Schedule of monitoring and deliverables for years 1 – 5 of the proposed monitoring designs.

Option A Rotating Basin Design only

	Year 1 FY18/19	**Year 2 FY19/20**	**Year 3 FY20/21**	**Year 4 FY 21/22**
Monitoring	24 samples each in Subregions 1, 2 (48 samples total)	24 samples each in Subregions 3, 4 (48 samples total)	24 samples each in Subregions 5, 6 (48 samples total)	
Reporting/ Deliverables	Annual Field Report	Annual Field Report	Annual Field Report	**Summary and Interpretive Report**

Option B Hybrid design: Rotating Basin + 2 fixed sites

	Year 1 FY18/19	**Year 2 FY19/20**	**Year 3 FY20/21**	**Year 4 FY 21/22**	**Year 5 FY22/23**
Monitoring	24 samples in subregion 1; 12 samples in subregion 2 *(50% of n = 24 needed, complete in year 2)* 6 samples at each of 2 fixed sites (48 samples total)	12 samples in subregion 2; 24 samples in subregion 3; 6 samples at each of 2 fixed sites (48 samples total)	24 samples in subregion 4; 12 samples in subregion 5 *(50% of n = 24 needed, complete in year 4)* 6 samples at each of 2 fixed sites (48 samples total)	12 samples in subregion 5; 24 samples in subregion 6; 6 samples at each of 2 fixed sites (48 samples total)	
Reporting/ Deliverables	Annual Field Report	Annual Field Report	Annual Field Report	Annual Field Report	**Summary and Interpretive Report**

Rotating Basin - Stratified Probabilistic Sampling Design

The main advantage to using a random sampling design is that it allows us to analyze the data with lower chances of errors. Statisticians have developed procedures for assessing the margin of error or confidence interval of estimates. It lets us draw conclusions about the population we are interested in (in this case, water quality in the Delta) and understand the uncertainty associated with these estimates. By further subdividing the Delta into subregions, it lets us assess whether there are differences in water quality within the Delta, i.e. between one subregion and others.

A pool of potential sample locations will be developed for sample collection. Sample collection locations will be randomly selected from within each of the subregions. Each subregion will be sampled at the frequency and number of samples described below at locations randomly selected from a pool of potential sampling locations. Sampling locations within a subregion will be selected using the Generalized Random-Tessellation Stratified (GRTS) method which identifies monitoring sites based on a stratified random selection process (NPS 2017). These locations will be selected and mapped during the development of the Quality Assurance Project Plan (QAPP) before the beginning of sampling. As is typical with randomized trials, we will "oversample," identifying more sampling locations than needed in the event where a location is inaccessible or impractical to reach.

Further Stratification by Hydrographic Features

Stratifying the population helps to ensure that the sampling program is representative of the Delta. Therefore, Delta subregions will be further stratified based on hydrography and water body characteristics. The random sampling algorithm (GRTS) is based on area, and is biased towards placing more sample points in larger water bodies, simply because of their larger surface area. Stratifying by hydrographic characteristics will help ensure that not all of the samples are in large channels and that we also collect samples from smaller sloughs and creeks. Our working hypothesis is that the smaller sloughs and creeks are often closer to sources and have less initial dilution, and less tidal flushing, and thus have the potential for higher pesticide concentrations. These smaller water bodies may also have high habitat value. The sample frame and strata will be planned in collaboration with the Delta RMP Pesticides Subcommittee and field sampling crews and outlined in the Quality Assurance Program Plan (QAPP) from July to September 2018.

In order to draw conclusions with reasonable statistical confidence, we would like to have approximately 30 samples within each of the strata. Therefore, in order to make conclusions about conditions in any of the strata such as "shallow water," we should collect at least 20% of the samples from within that strata. The Pesticide Subcommittee has had a preliminary discussion where it was suggested to split the number of samples would be 50% in open water (wide river channels and lakes) and 50% in shallow regions (sloughs, tributaries, and backwater reaches). Others have suggested that a ratio like 60/40 or 70/30 would be preferable. This ratio could be based on the available surface area of each water body type in a subregion, their linear distance, or water volume. Such details will be worked out during the development of the detailed sampling plan and documented in the project QAPP.

One proposed method has been to split Delta waterways into “open water” vs. “shallow water.” A preliminary stratification is shown in Figure 3. The potential sample frame in Figure 3 is based on a GIS datalayer developed by DWR for a similar purpose, to draw sampling points for benthos monitoring (Elizabeth Wells, DWR, personal communication). The data is a polygon layer representing Delta waterways. It was based on the National Hydrography Dataset (NHD) created by the USGS. DWR technicians refined the basic hydrology and also broke the overall areas into Bay-Large, Bay, River, River-Large, Lake, and Slough, in addition to Island (non-target) and identified other inaccessible areas. The data layer was further refined by removing areas that boat captains deemed inaccessible because of hazards or emergent vegetation that makes sampling impractical. To add depth to this datalayer, and SFEI geographer/GIS technician merged this with data that was compiled from a variety of sources previously for the study *A Delta Transformed* (Robinson et al. 2014). Here, we defined “deep water” as greater than as deeper than 2m (6.6 feet). We divided channels where appropriate, but did not cut channels longitudinally. Further refinement of the sample frame will be made in consultation with the USGS field crews, who may be using a smaller boat than the vessel used by DWR and may be able to reach shallower waters.

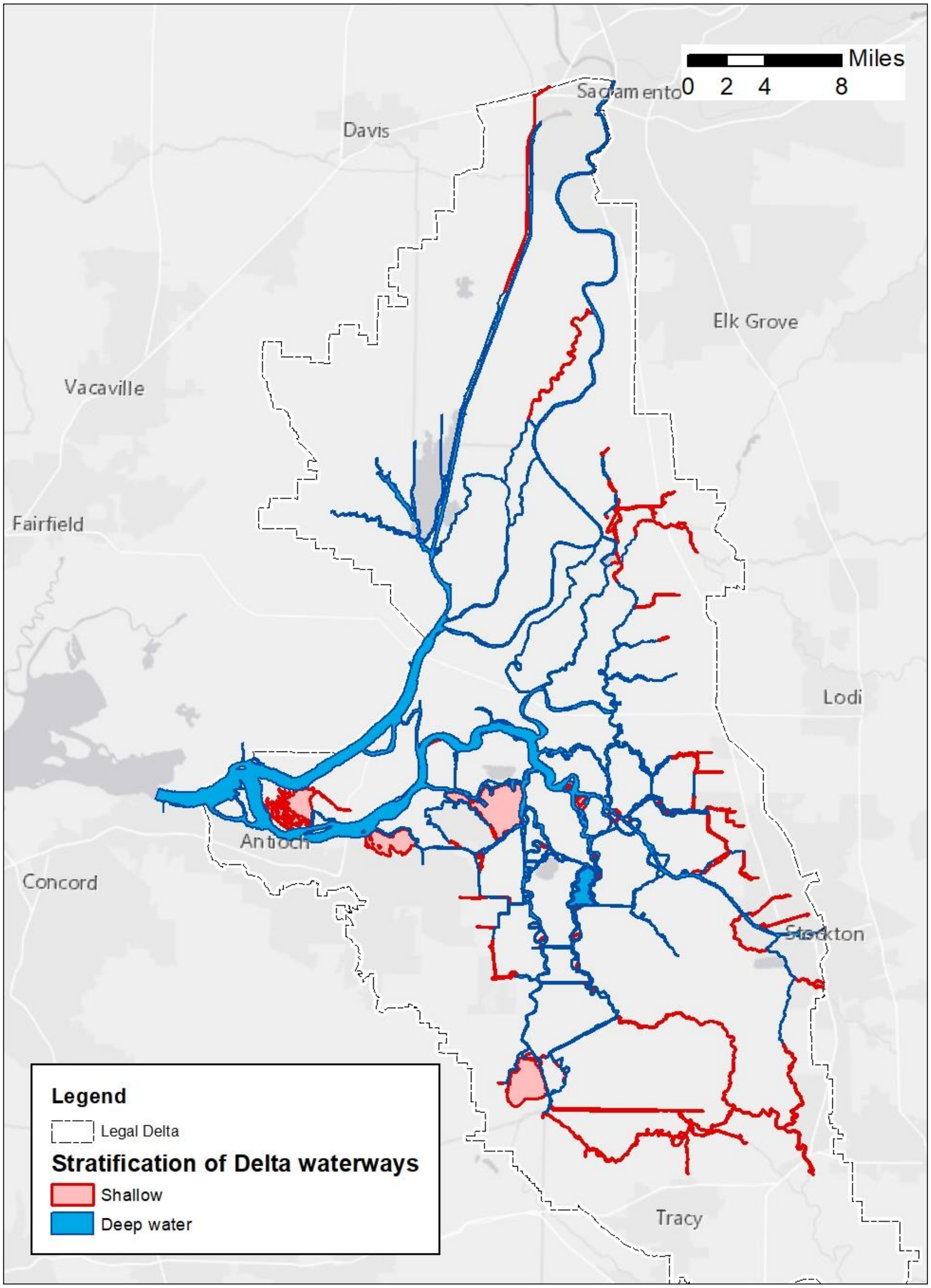

Figure 3 Stratification of Delta waterways into shallow and deep water (>2m)

Another method of stratifying Delta waterways has been proposed related to hydrologic connectivity, flow-through and circulation. The working hypothesis is that channel edges can have high habitat value and be areas of high pesticide concentrations due to localized drain inputs. We have not yet gotten to the level of detail in the sampling plan to develop this datalayer. We may be able to do this using hydrodynamic model outputs that were developed as a part of recent Delta RMP nutrients studies (Guerin 2015). For example, Figure 4 shows the water "age" or exposure time. These data are based on model results by RMP subcontractor Resource Management Associates (RMA). Note that this particular map represents a simulation of June 2011 under a particular set of circumstances (e.g. Delta Cross Channel open, Old River Barrier closed for part of month). We have access to dozens of maps (and the underlying data) for similar simulations, under periods of low, high, and average flow. These data could be used to stratify the Delta into areas of "high" and "low" connectivity. This will require a number of assumptions and requires us to set some arbitrary cutoff for the difference between high and low connectivity. This stratification can be done in collaboration with the Delta RMP's Technical Advisory Committee and Pesticides Subcommittee who have significant amount of local knowledge of the Delta.

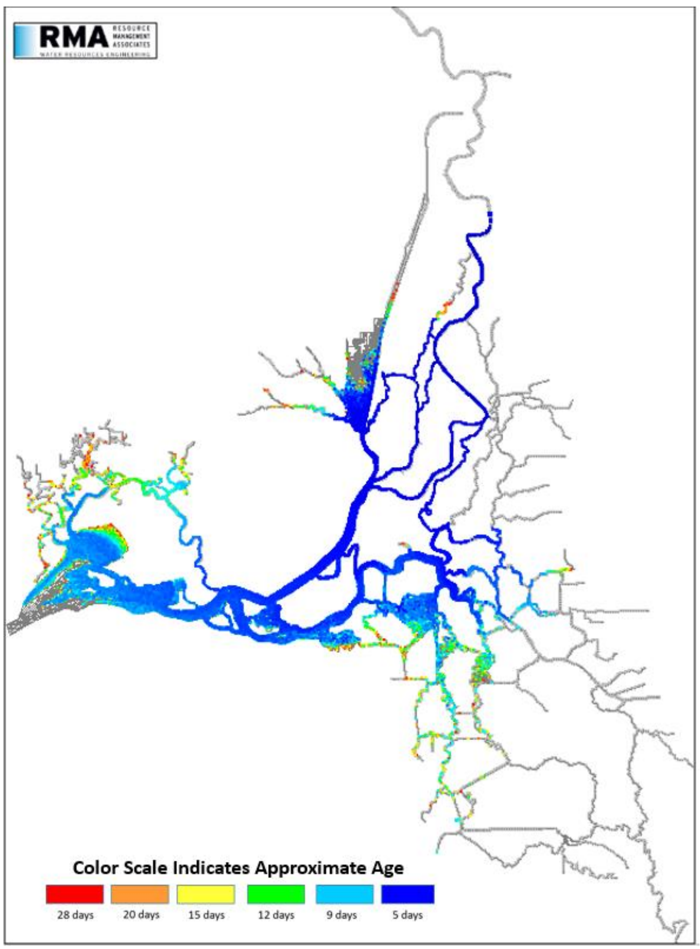

Figure 4 Example fate and age/exposure time map produced by RMA for the Delta RMP 2018 nutrients modeling study.

Fixed Sites

Option B, the hybrid option, includes sampling at two fixed sites. Some pesticides subcommittee members expressed a strong preference for continuing to monitor at fixed sites. These are "critical to being able to characterize the pesticides in the Delta in terms of the frequency and timing of toxicity, detections and exceedances. All of this is essential to answer Management and Assessment Questions S&T 1.1 and S&T1.2 and the temporal aspect of question S&T2. [See Table 1 on page 11.] The fixed sites proposed are good representatives of areas that receive a mix of urban and agricultural discharges at concentrations of concern in Delta Receiving waters."

The first of the two sites, San Joaquin River at Buckley Cove is on the main stem of the San Joaquin River, below the influence of the Stockton urban area. It is an integrator site with a variety of land uses upstream. The second site, Ulatis Creek at Brown Road represents agricultural and urban influences in the North Delta discharging to the ecologically significant Cache/Prospect Slough complex. The rationale behind selecting peripheral "integrator" sites is to characterize the spatial and temporal variations in loadings to the inner Delta as a first step. A monitoring design to measure loads of pesticides to the Delta is an appropriate first step toward understanding conditions in the inner Delta.

Strengths and Limitations of the Proposed Monitoring Designs

Table 5 describes the strengths and limitations of the rotating basin probabilistic design (adapted from NWQMC 2017). Table 6 covers the advantages and disadvantages of fixed site monitoring.

Table 5 Strengths and limitations of the rotating basin probabilistic design (included in both Option A and Option B).

Strengths	Limitations
Estimates the extent and proportion of the population in condition classes (i.e. meeting or not meeting standards) with known levels of precision and documented margin of error. Identifies patterns as well as associations between indicators to broad analysis of stressor/response signals. Focused approach in a smaller geographic areas allowing for a more robust characterization in the years when the subregion is sampled. Travel time to sites during each sampling event is reduced through selection of rotational areas. Smaller geographic scale allows for more detailed analysis of potential sources. Rotating basin designs paired with long-term trend monitoring at "integrator" sites overcome the lack of ongoing data between rotations. The approach is flexible regarding within-basin study designs, and adaptable to a variety of monitoring questions.	Not designed for localized or site specific characterizations, though data at sites sampled supports detailed characterizations. Generally not applied to characterize local, site specific effectiveness assessments (e.g. Total Maximum Daily Loads, TMDLs, Best Management Practices, BMPs). As with all designs, changes detected by repeat surveys must consider hydrologic and other variable factors. It will take 3 years or more to monitor the entire Delta. Annual changes in weather, stream flow, and other variables make it challenging to compare assessments between subregions. Detecting trends within a subregion will take longer with data collected on three-year intervals than it would if samples were collected annually.

Table 6 Strengths and limitations of fixed site monitoring (included in Option B only).

Strengths	Limitations
Provides long-term, in-depth water quality information at specific locations. Supports conclusions about conditions at specific sites or areas or concern. Because it is holding other variables constant by repeatedly sampling the same location, increased power for trend detections at the fixed sampling locations. Ability to determine frequency of exceedance of water quality thresholds, how conditions vary by season or flow regime, and, possibly, the effectiveness of regulatory actions.	Usually biased sites that provide specific information that cannot be extrapolated to make conclusions about the condition of the entire Delta. Under this proposal's Option B, adding fixed sites reduces the number of samples per year under the rotating basin probabilistic design, meaning this component of the study will take longer and cost more money to complete (4 years rather than 3 years to cover the whole Delta).

Data Collected

Samples will be collected by boat by crews from the USGS Organic Chemistry Research Laboratory (OCRL). The water quality parameters to be analyzed are described below. Additional samples (around 20% of samples) will be analyzed for quality assurance and quality control purposes. This will include lab and field replicates, matrix spikes, matrix spike replicates, field blanks, filter blanks, method blanks, continuous calibration blanks, initial blanks, and laboratory control samples. Table 13 in Appendix 1 shows the analysis method, reporting limit, and method detection limits for all parameters.

Conventional Parameters

Basic field measures of water chemistry (dissolved oxygen, pH, temperature, specific conductivity, turbidity) will be made at each monitoring site during each event. Other conventional water quality parameters are analyzed in the lab, including total alkalinity, ammonium as N, hardness.

Habitat Parameters

The field crew will make a number of observations about the sampling location, and record these on a field sampling data sheet. These observations are somewhat confusingly referred to (by USGS, SWAMP and others) as "habitat parameters," even though we are not specifically monitoring wildlife habitat. Table 7 shows the elements captured in this form. In the past, Delta RMP CUP monitoring visited the same 5 sites monthly, and therefore, each site was well known to us, and there was not much to be gained from these observations. However, as we will be monitoring dozens of new, randomly-selected locations, it will be important to record conditions at each site, particularly anything out of the ordinary. These observations may be useful for interpreting the pesticide and toxicity results for that station.

We may wish to collect additional information to help understand factors affecting each sampling location more than the standard field form describes. This may include upland land use (e.g., urban, ag, native), cover, submerged or emergent aquatic vegetation presence/absence. This data collection element will be discussed by the TAC during the development of the detailed sampling and analysis plan and documented in the QAPP. This is important as it is typically a much greater effort – and more prone to error - to describe each site 1 to 2 years after sample collection when writing an interpretive report, if data are not collected at the time of sampling or soon after.

Table 7 Habitat parameters recorded by field crews at each sampling location.

Parameter	Possible responses
Site odor	None, Sulfides, Sewage, Petroleum, Smoke, Other
Sky code	Clear, Partly cloudy, Overcast, Fog, Smoky, Hazy
Other presence	Vascular, Nonvascular, Oily Sheen, Foam, Trash, Other
Dominant substrate	Bedrock, Concrete, Cobble, Boulder, Gravel, Mud, Unknown, Other
Water clarity	Clear (see bottom), Cloudy (>4" visibility), Murky (<4" visibility)
Water odor	None, Sulfides, Sewage, Petroleum, Mixed, Other
Water color	Colorless, Green, Yellow, Brown
Overland runoff (last 24 hours)	None, light, moderate/heavy, unknown
Observed flow	NA, Dry Waterbody bed, No Observed Flow, Isolated Pool, Trickle (<0.1 cfs), 0.1 - 1 cfs, 1-5cfs, 5-20 cfs, 20-50cfs, 50-200cfs, >200cfs
Wadeability	Yes, No, Unknown
Wind speed (Beaufort scale)	
Wind direction	
Precipitation (at time of sampling)	None, Fog, Drizzle, Rain, Snow
Precipitation (last 24 hours)	Unknown, <1", >1"
Occupation Method	Walk-in, Bridge, Other
Starting bank	
Distance from bank	
Stream width	
Water depth	
Location	Bank Thalweg, Mid-channel, Open Water
Hydromodification	None, Bridge, Pipes, Concrete channel, Grade control, Culvert, Aerial zipline, Other

Current Use Pesticides

Pesticide chemistry analysis will be performed by the USGS Organic Chemistry Research Laboratory (OCRL) in Sacramento. Samples will be analyzed for total and dissolved pesticide concentrations for 174 current use pesticides and degradates. Compounds include fungicides, herbicides, insecticides, degradation products, and “other.” Examples of compounds classified as “other” include pyriproxyfen which is a hormone and insect growth regulator, and piperonyl butoxide, which is a “synergist” which increases the potency of certain other pesticides. Water samples will be processed and analyzed by liquid chromatography tandem mass spectrometry (LC/MSMS) or gas chromatography mass spectrometry (GC/MS. These analysis methods are have been previously described in the Delta RMP’s FY15/16 data report (Jabusch, Trowbridge, Heberger, Orlando, et al. 2018). A full list of analytes, methods, and reporting limits is given in Appendix 1.

These analytes are the same as those previously monitored during the first phase of the CUP program in 2015 and 2016, plus the addition of 19 new analytes for which the lab has recently developed a method. The new analytes are the following:

Acetochlor	Herbicide
Benzovindiflupyr	Fungicide
Carboxin	Fungicide
Chlorfenapyr	Insecticide
Dichlorvos	Insecticide
Etoxazole	Insecticide
Flubendiamide	Insecticide
Fluopyram	Fungicide
Flupyradifurone	Insecticide
Imidacloprid urea	Insecticide
Isofetamid	Fungicide
Oxathiapiprolin	Fungicide
Penthiopyrad	Fungicide
Pyriproxyfen	Other
Sulfoxaflor	Insecticide
Tebufenozide	Insecticide
Thiamethoxam Degradate (NOA-407475)	Insecticide
Thiamethoxam Degradate (CGA-355190)	Insecticide
Tricyclazole	Fungicide

Some compounds are highly water soluble, while others tend to be adhere to sediments and other particles. In order to gain a full picture of pesticides in the environment, OCRL will measure both the dissolved fraction in water and the fraction associated with suspended sediments. (Note that we are not proposing to measure pesticides in bedded sediment at this time.) Measuring pesticides that are both dissolved in water and on suspended sediments can help give greater insight into the fate and transport of different compounds. The way chemicals move through and impact the environment can depend strongly on their physical and chemical properties – some are highly soluble in water, while others tend to adsorb strongly to sediments particles. Of the 174 compounds measured in water, the lab is able to analyze 139 compounds in suspended sediment.

Copper

Copper is an ingredient used in herbicides, and is used in the cultivation of rice, as well as to control aquatic plants and algal blooms, and has been previously suggested as a possible cause of aquatic-biota toxicity in the Delta. However, it is also a natural occurring and ubiquitous trace element that may originate from other sources.

Samples will be sent to the USGS National Water Quality Laboratory (NWQL) in Denver for analysis for copper. Copper will be analyzed at the NWQL using the method described in Techniques and Methods Book 5-B1 (Garbarino, Kanagy, and Cree 2006). It is also important to measure other ancillary parameters in order to interpret whether copper is bioavailable and potentially toxic. Copper has a complex chemistry and its toxicity can vary widely from place to place due to local conditions (e.g., pH, ionic composition, presence of natural organic matter). Hardness-adjusted thresholds provide a simplified approach to address water chemistry and bioavailability but they do not directly consider other water chemistry parameters (e.g., pH and DOC) that affect bioavailability and toxicity of dissolved copper. More complex methods for evaluating copper toxicity take into account additional water quality parameters to estimate bioavailability. For example, EPA's National Recommended Water Quality Criteria (2017) considers how various water quality parameters affect copper toxicity using the Biotic Ligand Model (BLM). Lab analysis of water samples additional ancillary parameters will help us to interpret the copper measurements using the methods described above.

Ancillary Parameters

To assist with interpreting the bioavailable fraction of pyrethroid pesticides, samples will also be analyzed for ancillary parameters by the USGS National Water Quality Laboratory (NWQL). Other parameters measured by NWQL are:

Fraction	**Water Quality Parameter**
Dissolved	Dissolved Organic Carbon
Particulate	Carbon, Total
Particulate	Nitrogen, Total
Particulate	Particulate Organic Carbon
Particulate	Total Inorganic Carbon
Particulate	Total Suspended Solids

Dissolved organic carbon will be analyzed at the NWQL using the method described in OFR 92-480 (Brenton and Arnett 1993). Particulate organic carbon, total particulate inorganic carbon, total particulate nitrogen, and total particulate carbon will be analyzed at the NWQL using EPA method 440.0 (Zimmerman, Keefe, and Bashe 1997).

Aquatic Toxicity Testing

Under the proposed monitoring design, we plan to test ambient surface water samples for acute and chronic aquatic toxicity with five different organisms shown in Table 8 below. Test organisms were selected based on updated SWAMP guidance (Anderson et al. 2015), past Delta RMP monitoring experience, and input by stakeholders and technical experts.

The use of midge larvae (*Chironomus dilutus*) is new to the Delta RMP. *Chironomus dilutus* has been listed as a valid alternate species for over a decade in EPA's freshwater acute toxicity test manual (USEPA 2002). EPA and USGS developed species-specific methods that are currently out for review within these agencies. *Chironomus* toxicity data (SWAMP-funded) could support method validation efforts. More information about *Chironomus* is included in Appendix 4. Detailed information on the test methods for the other 4 organisms can be found in the *Delta RMP Current Use Pesticides Year 1 Data Report* (Jabusch, Trowbridge, Heberger, Orlando, et al. 2018).

Table 8 Proposed aquatic toxicity tests

Test organism	Endpoints	Rationale for including
Ceriodaphnia dubia, a daphnid or water flea	survival, reproduction	Sensitive to organophosphate pesticides
Hyalella azteca, an aquatic invertebrate	survival	Sensitive to pyrethroids
Selenastrum capricornutum, a single-celled algae (also known as *Raphidocelis subcapitata)*	growth	Sensitive to herbicides
Chironomus dilutus (formerly *Chironomus tentans*), midge larvae	growth, survival	Sensitive to fipronil and more sensitive in chronic exposures to imidacloprid than *C. dubia.*
Pimephales promelas, fathead minnow	growth, survival	Chronic and acute effects on whole organism growth and survival

Stakeholders have asked questions about how results from Chironomus toxicity data could be used by regulators. Currently all existing Chironomus toxicity data in CEDEN is flagged as "screening." This may change in the upcoming year if the State Water Board publishes method quality objectives (MQOs) for certified labs to follow.

Any data can be used by state regulators to list a water body as impaired under section 303(d) of the Clean Water Act. It is the Regional Board's decision whether or not to use data for a particular purpose. Staff may use any and all data, regardless of whether it is flagged as "screening" "survey" or has any other QA flag attached. If a group (i.e. regulated entity) wants to invalidate data for some reason, it would be incumbent upon them to contact the 303(d) unit at the appropriate Regional Board and make the case that data should not be used. In brief, anything in CEDEN may be used for regulatory purposes, regardless of flags/QA codes, and it is up to the Regional Board to make the decision what they use. Also, some Regions have begun using data from sources other than CEDEN.

Rainbow trout - It has been suggested to add rainbow trout (*Oncorhynchus mykiss*) to the suite of test organisms. This would be a useful test organism as it is more closely related to threatened and endangered species in the Delta. However, this test is not covered under the SWAMP contract with the testing lab. We have held discussions with NOAA fisheries, who have indicated that they will consider funding beginning in the *next* fiscal year, FY19/20.

Toxicity Identification Steps

Consistent with monitoring and assessment question S&T1.1A ("If samples are toxic, do detected pesticides explain the toxicity?"), a Toxicity Identification Evaluation (TIE) s triggered when the sample experiences a 50% reduction in the endpoint (e.g., survival) compared to the control. A TIE is an investigative process that uses laboratory modifications of test sample chemistry and resulting changes in toxicity to identify the constituent group (e.g., organophosphates) that are the likely cause(s) of toxicity.

This proposal includes a budget to conduct up to 4 TIEs during the water year. The decision to conduct a TIE is based upon consideration of multiple factors such as the magnitude of toxicity. magnitude of toxicity present in the sample matrix is an important consideration because a moderate to high level of toxicity typically yield results that are more successful.

Data Management and Quality Assurance

Data will be reviewed for overall quality/usability according to SWAMP and EPA data validation procedures. SWAMP program staff will be responsible for managing the toxicity data and performing quality assurance. SWAMP is working to identify additional QA or Corrective Actions that will be done in 2018/19 to address past deviations or errors. This may include, for example, performing an independent QC check on 10% of toxicity bench sheet calculations that would trigger a more thorough audit and corrective actions by the lab if errors are found.

SWAMP's QA program is described in its *Quality Assurance Program Plan* (2017). SWAMP has created measurement quality objectives (MQOs) establishing requirements and recommendations for the various tests and measurements used for SWAMP's water-quality monitoring projects. SWAMP's MQOs can be found on the SWAMP Wiki and the SWAMP webpage.

SWAMP managers have indicated that they will *not* be providing data analysis, reporting services, or QA summary/narratives for this project. We have added a small amount of budget (10 hours total) for ASC staff to review the toxicity data and prepare a brief QA summary of the toxicity data. To prepare the toxicity QA summary, ASC staff will download the toxicity data from CEDEN, run standard QA/QC analyses, and write a short memo describing whether the measurement quality objectives (MQOs) described in the Quality Assurance Program Plan (QAPP) were met, and describing any deviations from the QAPP. ASC will not be adding any new QA flags to the data, nor will we describe deficiencies identified by the SWAMP Quality Assurance Officer, or corrective actions that were taken.

Delta RMP stakeholders have expressed a strong interest in receiving detailed updates regarding any deficiencies by the laboratories, communications, and corrective actions. The SWAMP QA Officer has indicated that SWAMP staff are able to provide us with a "simple summary statement from SWAMP including the following: 'issues were detected, a correction action report was completed and approved, and laboratory performance will be assessed regularly.' Discussing the details of what steps were taken with stakeholders is not appropriate. Nor will we allow for additional requests to be made of our Contractor [the UC Davis toxicity lab]" (Melissa Morris, personal communication, June 27, 2018).

In addition, we have arranged for AHPL to submit provisional electronic data and documentation of their processes and controls after each and every monitoring round. These submittals will be in lieu of an annual lab report, which they have provided in years 1 and 2 of pesticide monitoring. ASC's Data Management and Quality Assurance team will do a brief review of the submitted data, and we will distribute the information to TAC and Pesticides subcommittee members so that those who are interested can review this information.

The Aquatic Science Center (ASC)'s Data Services team (DS) will be responsible for handling and reviewing data generated by field crews and for chemical analyses by the USGS labs. The staff of the OCRL performs certain QA checks on the data before submitting it to ASC. For more information about QA performed by the USGS lab, see Appendix 2. ASC's Quality Assurance Officer (QAO) and staff independently recalculate any QC metrics reported by the lab, as an additional layer of verification of the results.

The review process consists of ASC's DS team checking that results are received for all samples collected and that the lab reported results for the analytes requested in the contracts. Staff will check in the data as it arrives, and perform a partial analysis of the data to verify that it is complete and meets certain minimum acceptability criteria. This will help us to identify any potential problems in a timely manner and make any necessary corrective actions. For more information, see the *Delta RMP Data Management and Quality Assurance Standard Operating Procedures* (Franz et al. 2018).

Data is standardized by ASC's DS team using California Environmental Data Exchange Network (CEDEN) templates, controlled vocabulary, and business rules. Data is reviewed by

ASC's QA officer or designee (under the supervision of the QA Officer) to ensure sufficient laboratory control samples are analyzed in order to evaluate whether samples are meeting Measurement Quality Objectives (MQO) as stipulated in the Quality Assurance Project Plan (QAPP). These processes are necessary to ensure data are usable by project staff, regulatory agencies and members of the public.

Five evaluations make up the core of the QA-review process:

1. **Data completeness:** Has the lab submitted all expected data, including the correct number of QA samples? Were contract and QAPP expectations met?
2. **Sensitivity**: Were the analytical methods sensitive enough to get detectable results?
3. **Contamination**: Was there contamination present in any of the sample batches?
4. **Accuracy**: Did the lab reliably measure known concentrations?
5. **Precision**: Was the lab able to consistently obtain the same result in its analysis of replicate or duplicate samples?

Deliverables for this step include a tabular summary of the data (typically in an Excel spreadsheet), and a memo from ASC's QA officer summarizing the quality assurance (QA) review. The QA review will begin after we receive final dataset from the laboratories, typically about 3 months after the last samples are collected, planned for December 2019. The QA memo will be written in the spring of 2020 and sent to TAC members in the first quarter of 2020. A timeline of planned deliverables is shown in Table 10 on page 44.

QAPP Modifications Needed

Several important details have been left open-ended, to be developed in the future. It is important that these details be set before monitoring begins in October 2018. This proposal follows a similar process that SEFI-ASC scientists have used successfully over the last 20 years: first we draft a proposal that outlines a monitoring program, and then develop a more detailed "sampling and analysis plan" after funding is approved. This is appropriate because developing this plan requires an investment of time and money that would not be well spent in the proposal stage. Because the Delta RMP has a detailed Quality Assurance Program Plan (QAPP), it is appropriate to add these details to this document. Some of the important details to be included in the QAPP are described below.

The QAPP will include measurement quality objectives for all parameters. The current Delta RMP Quality Assurance Program Plan (QAPP version 3.5, dated March 14, 2018) does not include a description of monitoring of pesticides and toxicity, as the program took a hiatus from monitoring these parameters in FY17/18. Previous versions of the QAPP (version 2.2, dated September 30, 2016) described pesticides and toxicity monitoring. Much of this information is still useful and relevant; however, certain updates and modifications will need to be made to the QAPP following approval of this monitoring plan. We expect to draw heavily on the QAPP from FY16/17, and to update it as necessary.

Budget to update the QAPP was approved by the Steering Committee as part of the FY18/19 Workplan. The sampling and analysis plan will rely heavily on standardized methods for data/sample collection and analysis. A QAPP will describe these specific activities and be sufficiently robust to achieve the study goals. As shown in the schedule of deliverables (Table 10 on page 44), QAPP updates will be done from July to September 2018.

ASC staff will work closely with the pesticides subcommittee and our science advisors as we develop additional guidance and documentation to include in the QAPP. In addition, the draft QAPP will be made available to the TAC and external stakeholders for review (planned for August 2018), and their comments and input solicited. At least two meetings with the pesticides subcommittee will be held from July to September to discuss the detailed sampling plan and QAPP amendments. New elements to be added to the QAPP include the following items:

Sample location selection and pool of possible locations - Development of the final geographic datalayer of Delta waterways to form the basis of our population or the "sample frame" from which random sampling locations will be drawn. Stratification of Delta waterways, as described above on page 20. Selection of sample locations using the GRTS method.

Additional EC-based control and data interpretation protocols for *Ceriodaphnia dubia* toxicity tests - In the first two years of Delta RMP monitoring, it was noted by technical reviewers that there may be an interference with toxicity testing of C. dubia when sample water had had unusually low levels of salinity/conductivity, as indicated by measurements of electrical conductivity (EC). *C. dubia* reproduction is known to be sensitive to low conductivity. The Delta RMP Pesticides subcommittee has been discussing this issue with the SWAMP QA team and the UC Davis aquatic toxicity lab manager. Our goal is to put in place revised procedures in the form of Measurement Quality Objectives (MQOs) that will increase the reliability of the test in low-EC waters, most likely by adding an additional control batch when EC is in the range of 100 – 200 μS/cm, and establishing protocols for performing statistical comparisons to the most appropriate control. It is our current understanding that Bryn Phillips of the UC Davis Granite Canyon lab is currently drafting a tech memo for SWAMP that will provide guidance on this issue. For additional information on this issue, see the tech memo from the Jan 9, 2018 Pesticides Subcommittee meeting (available upon request or on the TAC workspace website.)

Toxicity test methods for *Chironomus dilutus* – There are at present no standardized test methods for water-only testing with midge larvae (*Chironomus dilutus*). We will work with the lab, SWAMP and our technical advisors to determine the most appropriate methods with a view to making test results reliable, repeatable, and comparable with results obtained by others. For more detailed information on method development for water-only toxicity testing with *Chironomus*, see Appendix 4.

Data Analysis and Presentation

The goal of Delta RMP monitoring is to help answer the management and assessment questions shown in Table 1. As a part of the Data Quality Objectives (DQO) process, the Pesticide Subcommittee has worked to convert these questions into hypotheses, or specific, quantitative decisions to be made based on the data collected. The next step in the DQO process is to "Specify tolerable limits on decision errors." Data quality objectives (DQOs) for the monitoring program are shown in Table 9. The decision rules in Table 9 anticipate that parametric statistical methods will be used. If data are non-normally distributed or regression residuals are non-normal, there may be a need to use nonparametric statistical analysis methods. Non-parametric methods may require larger sample sizes to answer the assessment questions listed in Table 1.In the table, we set the parameters for tolerable limits on decision errors (referred to by statisticians as *alpha* and *beta*) based on commonly used assumptions in science. We chose a significance level (alpha) of 0.05 for a one-tailed hypothesis test. For example, suppose we are testing whether more than 1% of river miles have a pesticide concentration exceeding a threshold. With alpha = 0.05, there is a 5% chance of a false positive with hypothesis testing (incorrectly concluding that concentrations in these river miles exceeds the threshold.) The choice of beta of 0.2 is the probability of a false negative. Statistical power is 1 – beta or 0.8. This means, for example, that we have only a 20% chance of incorrectly concluding that a predicted pesticide concentration does not exceed a threshold.

Water quality thresholds – The simplest and most straightforward way of determining whether a chemical may be causing an adverse impact on a waterway is to compare observed concentrations to a water quality threshold or benchmark. When a threshold has the force of law, it is referred to as a standard, or in California, a water quality objective. However, state and federal regulators have written standards for only a few current use pesticides. For example, the Central Valley Regional Water Quality Control Board has established water quality objectives for chlorpyrifos and diazinon that cover much of the Central Valley including the Delta. [1] For the hundreds of other current use pesticides, there are neither national water quality criteria recommended by the EPA, nor are there state water quality objectives.

Comparing ambient concentrations to benchmarks is a useful first step in the process for interpreting pesticide data and evaluating relative risk. The choice of a threshold is important. If our monitoring shows that concentrations exceed a threshold, the implication is that there is a problem. Yet, the choice of a threshold is a complicated technical question. *We have not explicitly defined thresholds in this proposal,* in part because this work is ongoing, as part of an analysis of pesticides and toxicity data contracted by the Delta RMP to the firm Deltares.

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[1] See *Amendments to the 1994 Water Quality Control Plan for the Sacramento River and San Joaquin River Basins* (Central Valley Regional Water Quality Control Board, 2016), Table III-2A, Specific Pesticide Objectives, on page III-6.01. Chronic toxicity is based on the average concentration over a 4-day period.

Options for setting thresholds include aquatic life (AL) benchmarks published by the US EPA Office of Pesticide Programs (OPP). OPP benchmarks were developed by the U.S. EPA for use in the agency's risk assessments conducted as part of the decision-making process for pesticide registration. The OPP benchmark values are based on the most sensitive species tested within taxonomic groups (fish, invertebrates, vascular and non-vascular plants). They represent the lowest toxicity values available from peer-reviewed data with transparent data quality standards. OPP benchmarks may or may not be useful for interpreting Delta RMP toxicity data. However, these thresholds are broadly relevant to protecting aquatic life. It has also been suggested by TAC members that it may be appropriate to divide OPP aquatic life benchmarks by a safety factor of 5 or 10. This would in line with the precautionary principle, and consistent with the CVRWQCB's Basin Plan, which states that standards will be based on the lowest LC50 divided by 10.[2]

Handling of non-detects – In the first two years of pesticide monitoring by the Delta RMP, many of the pesticide chemistry results were non-detects. Statistical methods should be chosen carefully for handling "censored data" (Helsel 2010). Common methods used in the past, such as substitution of zero or one-half the detection limit for non-detects is known to introduce bias in data analyses. One of our science advisors has recommended the use of the "Nondetects and Data Analysis (NADA)" package in R created by D. Helsel (USGS). We anticipate that useful guidance will also be developed as a part of the Delta RMP-funded interpretive report underway by Deltares.

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[2] See Amendments to the 1994 Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (2016), page IV-35: "Where valid testing has developed 96 hour LC50 values for aquatic organisms (the concentration that kills one half of the test organisms in 96 hours), the Board will consider one tenth of this value for the most sensitive species tested as the upper limit (daily maximum) for the protection of aquatic life. Other available technical information on the pesticide (such as Lowest Observed Effect Concentrations and No Observed Effect Levels), the water bodies and the organisms involved will be evaluated to determine if lower concentrations are required to meet the narrative objectives."

Table 9 Analytic approach, decision rule, and data quality objectives

Spatial extent of pesticides and toxicity (included in Options A and B)

Questions to Answer with Delta RMP Pesticide Data	Analytic Approach	Decision Rule	Data Quality Objectives	Power Analysis
Spatial extent of pesticide, toxicity occurrence For what percent of the subregion was aquatic toxicity and co-occurrence of pesticides greater than risk-based thresholds observed? Over what percentage of the subregion does a pesticide concentration exceed a threshold? Secondary objective that can be evaluated qualitatively: Identify spatial patterns in aquatic toxicity and pesticide concentrations within the subregion to inform decisions about sensitive habitats, sources, and strata for future designs.	1. Metric for toxicity: Binary variable (0/1 or True/False) indicating whether toxicity was observed, by species (as determined by a statistically significant reduction in an endpoint compared to control, to be described in greater detail in the QAPP). 2. Metric for pesticides: -Individual pesticide concentrations in water and suspended sediment - Individual pesticide frequency of exceedance of aquatic life benchmark. - Cumulative frequency of exceedance 3. Metric for determining cause of toxicity: outcome of Toxicity Identification Evaluations (TIEs)	Population estimates will be made using open source R software ('spsurvey').[3] Population estimates are not a statistical test. There is no null hypothesis. The result will be a percent of subregion water area meeting a certain condition such as: -Percent of subregion with statically significant aquatic toxicity -Percent of subregion with pesticide concentrations above risk based thresholds -Percent of subregion with significant toxicity AND pesticide concentrations above risk based thresholds	The sample size for each subregion should be large enough to be able to estimate the percent of subregion's water area with a certain condition with error bars of ±10%. Assume a Type 1 error of <0.05 and a Type 2 error of <0.2 (80% statistical power).	Because we are employing a random sampling design, a standard probability distribution known as the binomial distribution can be used to estimate of the upper and lower bounds of confidence intervals. The relationship between sample size and the confidence intervals around the cumulative distribution function are shown in Appendix 3 Figure 7 (see notes for assumptions). A sample size of n = 24 gives a 90% confidence interval of around ±13%. (This is acceptably close to our objective of ±10%.) More details on the power analysis presented in Appendix 3.

[3] https://cran.r-project.org/web/packages/spsurvey/spsurvey.pdf

Co-Occurrence of Pesticides and Toxicity (included in both Options A and B)

Questions to Answer with Delta RMP Pesticide Data	Analytic Approach	Decision Rule	Data Quality Objectives	Power Analysis
Causes of toxicity Evaluate the co-occurrence of aquatic toxicity and pesticides.	**Metrics for toxicity:** 1. Binary variable (0/1, or True/False) indicating whether significant toxicity was observed (stratified by species, and possibly by endpoint) 2. Continuous variable - Percent effect observed for individual toxicity tests: reduction in organism survival, reproduction, or growth compared to control. **Metrics for pesticides:** 1. Continuous variable: Observed concentration of individual pesticides, in ng/L 2. Binary variable (0/1 or True/False) Individual pesticide observations exceeding a risk threshold. 3. Frequency with which individual pesticides exceed a threshold. 4. Cumulative frequency of exceedance (for one or all pesticides) 5. Cumulative frequency of exceedance for classes of pesticides grouped by type or mode of action (organophosphate and pyrethroids) 6. Pesticide Toxicity Index*	**Statistical Test:** -Logistic Regression -Multivariate linear regression All data from all sites will be pooled for the test if and/or sites to be analyzed individually based on a statistical analysis of their similarity using Generalized Linear Models or Principal Components Analysis. Null hypotheses: Ho: Toxicity is not related to exposure to pesticides. (There is no relationship between pesticide levels and toxicity.) Ha: There exists a relationship between pesticide exposure and the toxicity.	The test should be able to detect a 5% effect** of pesticide exposure with a Type 1 error of <0.1 and a Type 2 error of <0.2 (80% power).	For the site on the San Joaquin River at Buckley Cove, to detect an effect size = 0.03 would require around 60 samples. In this context, an effect size of 0.03 is equivalent to a 3% increase in toxicity to macroinvertebrates for each unit increase in the Pesticide Toxicity Index (PTI). Requires 36 new samples at each site, or 6 years (i.e., collecting 6 samples per year at this fixed location). See Appendix 3 for more details on the power analysis.

* The Pesticide Toxicity Index (PTI) is a screening tool to assess potential aquatic toxicity of complex pesticide mixtures by combining measures of pesticide exposure and acute toxicity in an additive toxic-unit model. For more information, see “Pesticide Toxicity Index—A tool for assessing potential toxicity of pesticide mixtures to freshwater aquatic organisms” (Nowell et al. 2014).

** An effect size of 5% means that a unit increase of the PTI would result in a 5% reduction in a toxicity endpoint such as reproduction, survival, or growth. In general, large effect sizes (e.g. 50% reduction in survival) are easier to detect with smaller sample sizes, while small effect sizes (5% reduction in survival) are more difficult to differentiate from random chance and need a much larger number of samples to detect.)

Co-Occurrence of Pesticides and Toxicity (included in both Options A and B)

A goal of the proposed program is to better understand the role that contaminants play in contributing to toxicity in the Delta.[4] A statistical analysis of the first two years of Delta RMP monitoring data, described in more detail in Appendix 3, included an evaluation of power to detect statistical relationships between pesticide concentrations and toxicity across a range of sample sizes. In brief, an examination of data from the first two years of sampling did not find a statistically significant relationship between pesticide concentrations and observed toxicity. However, with two years of monthly data, collected under a variety of flow conditions, we now have a better estimate of the variability in predictor variables (pesticide concentrations) and response variables (toxicity endpoints such as percent reductions in survival or reproduction compared to a control).

The variability of these parameters is a key input into the power analysis. What the power analysis allows us to say is, if there is a relationship among these variables of a certain strength (or "effect size"), how many samples would be needed to recognize this relationship statistically, given a certain risk tolerance for a false conclusion? It was concluded that, based on the historically measured variability, and certain assumptions on the effect size we wish to detect and desired statistical power, that a total of 60 samples would be required. As we already have 24 samples at each fixed site to date, we need 36 additional samples giving us the ability to detect a correlation between pesticide concentrations and toxicity. Under this proposal, we would collect 6 samples per year at each of the fixed stations. Therefore, we would be able to detect such a correlation after another 6 years of sampling. For more details on the statistical power analysis, see Appendix 3.

Both monitoring design options can test for the co-occurrence of aquatic toxicity at measured pesticide concentrations using samples collected throughout the Delta. While toxicity might be found at any sample location in the Delta, the fixed sampling locations included in Option B had elevated toxicity in the past sampling years. Therefore, a similar frequency of toxicity is expected from the fixed monitoring stations under Option B to inform the co-occurrence analysis over the long term. The stratified probabilistic design would include surface water samples from areas with less dilution of pesticides (i.e., small tributaries), which could result in samples with a higher magnitude of toxicity than previously encountered. This would potentially allow for more TIEs to identify the causes of observed toxicity than was done in 2015-2017 Delta RMP sampling.

[4] Note however that under the "independent applicability policy" in water quality regulation, the cause of toxicity does not need to be demonstrated in order for regulators to list a water body as impaired. The toxicity water quality objective is a separate standard. However, it is desirable to determine which toxicant(s) are contributing to or causing toxicity.

Spatial Extent of Pesticides and Toxicity (Included in Options A and B)

With the data from the probabilistic design, we would like to know the percentage of each subregion where a pesticide concentration exceeds a benchmark, has observed toxicity, or where elevated concentrations of pesticides and toxicity co-occur. Using sample data from each of the subregions, we can construct cumulative distribution functions (CDFs) that show the distribution of a variable within that region. The CDF shows the percentage of stream miles that are less than or equal to each possible value of a variable. A hypothetical example is shown in Figure 5. In this case, the CDF could describe the concentration of a particular pesticide, the value of the Pesticide Toxicity Index (PTI), or the value of a toxicity endpoint. The CDF is useful for describing the overall condition of the resource being sampled, and lets you answer a number of questions, some of which are of interest to us. The important point is that with a larger number of samples, we will have smaller confidence intervals around the empirical CDF. We cannot do a conventional power analysis for the probabilistic design. However we can *a priori* estimate the size of the confidence intervals around the CDF, using the binomial distribution, and making some assumptions. Having "tighter" error bounds around the CDF is desirable for when we'll use it as a tool to make any kind of estimation.

A recent report from Oregon (DeGasperi and Stolnack 2015) which used GRTS to evaluate the status and trends of aquatic habitats describes how CDFs derived from sample data can be used to make inferences about the sampled populations:

> A CDF plot for a particular target sample population sampled in a particular year establishes a baseline against which future surveys (using the same probabilistic design) can be compared. Change over time (or between subpopulations of the target sample frame) can be detected not only in some measure of central tendency such as the mean or median value of a particular metric, but in certain portions of the CDF via visual comparison of the two (or more) CDF plots. Depending on the expected response of a particular metric to environmental stressors or to restoration measures, the CDF will be expected to shift to the left or right. Confidence intervals for each CDF provide a statistical basis for assessing change.

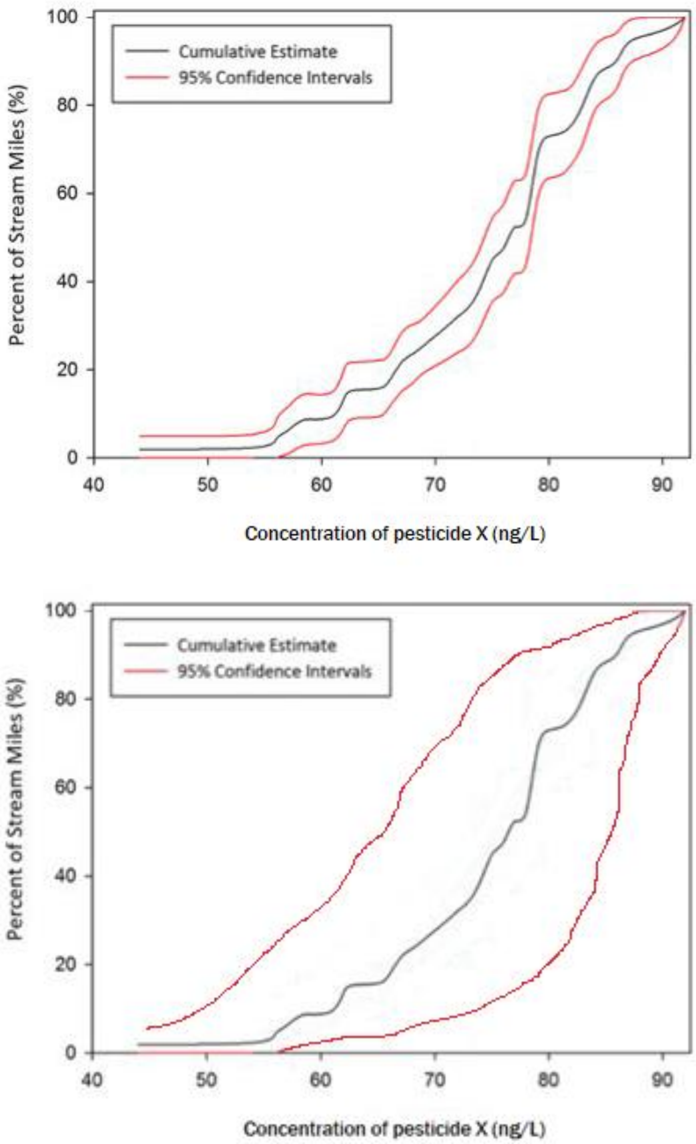

Figure 5 Hypothetical cumulative distribution functions for pesticide concentration in a Delta subregion.

In the hypothetical example in Figure 5, suppose we are seeking to answer the question, what percent of stream miles have a pesticide concentration < 75 ng/L. In the top figure, with more samples and smaller confidence intervals, the answer is 30% to 40%. In the bottom figure, with fewer samples and large confidence intervals, the answer is 15% to 80%. This is a made-up example, but it demonstates that a larger number of samples lets us make better estimations about the condition of the waterway.

In other words, we wish to make the confidence intervals as small as possible in order to make more reliable estimates about the sampled population. This means collecting a larger the number of samples, however there are constraints in terms of budget. No explicit guidance on the recommended sample size for GRTS survey designs exists. Budgetary and logistical constraints of individual study designs often dictate the level of effort employed. That said, probabilistic designs incorporating GRTS often aim to determine an estimate of a proportional extent, and thus refer to the binomial distribution to evaluate precision. In the scenarios analyzed in Appendix 3, a sample size of 30 would result in an estimated confidence interval of ±12%. A sample size of 24 gives only a slightly larger confidence interval of around ±13%. Increasing the sample size would not significantly impact on the size of the confidence interval, while fewer than 24 samples would increase the confidence interval substantially. Consequently, a sample size of 30 can be considered an "industry standard", and has, in the experience of our consulting statistician, been selected as a default sample size in order to make statistical inferences about condition, with a relatively low degree of error. A sample size o f24 is only slightly worse, and fits within available budget. Under Option A, this target sample size of 24 will be reached after 3 years. Under Option B, the number will be reached after 4 years. For more details, see the power analysis in Appendix 3.

Option B, which includes fewer random samples to add sampling at 2 fixed sites, can answer all of the same questions, although it may take longer to achieve the desired level of statistical power due to the smaller number of samples collected each year. However, it also adds the ability to detect trends at two locations in the Delta by repeatedly sampling at these two fixed sites. Further, fixed site sampling can be better at identifying associations among different water quality parameters, as we are holding more potentially confounding factors constant by sampling repeatedly at the same location.

Monitoring data can also be used to identify spatial patterns in aquatic toxicity and pesticide concentrations within the subregion to inform decisions about sensitive habitats, sources, and strata for future designs. The goal of most sample surveys is to estimate the proportion of a resource that is degraded. In this case, we will be able to estimate the percentage of each subregion in which a pesticide concentration exceeds a threshold.[5]

Numeric water quality standards exist for only a few current use pesticides. Therefore, we will compare observed pesticide concentrations to U.S. Environmental Protection Agency aquatic life (AL) benchmarks.[6] Benchmark values will be used as a first step in a process for interpreting

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[5] Not all Pesticide Subcommittee members agreed on the usefulness of assessing differences in water quality within or among subregions of the Delta. One member wrote, "I am less interested in the variation of pesticide concentration from one subregion to another sub region. There may be underlying reasons like different crop, climatic change, and pest patterns and therefore different pesticides used from one year to the next year. The overarching management question, 'Is there a problem or are there signs of a problem?" and the rotating basin design does not help to answer this. Especially, since we are only evaluating 2 subregions each year. If we find there is a problem, we will not return to that that sub-region again until another 3 years, and that is problematic."

[6] OPP benchmarks were developed by the U.S. EPA for use in the agency's risk assessments conducted as part of the decision-making process for pesticide registration. The OPP benchmark values are based on the most sensitive species tested within taxonomic groups (fish, invertebrates, vascular and non-vascular

pesticide data and evaluating relative risk. Aquatic life benchmarks may or may not be useful determining the cause of toxicity. However, these thresholds are broadly relevant to protecting aquatic life. The USGS OCRL's reporting limits are lower than the lowest benchmark for every analyte, as shown in Appendix 1. This appendix has a table showing all of the analytes to be measured, and lists the analysis method, method detection limit, and lowest aquatic life benchmark.

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plants). They represent the lowest toxicity values available from peer-reviewed data with peer-reviewed data quality objectives.

Proposed Deliverables and Timeline

Table 10 Timeline of proposed activities and deliverables.

	2018						2019												2020				2021				2022			
	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 0: QAPP Update		d	f																											
Task 1A: Year 1 Sampling																	d		f											
Task 1B: Year 1 Data mgmt and QA																			d	f										
Task 2A: Year 2 Sampling																						d	f							
Task 2B: Year 2 Data mgmt and QA																						d	f							
Task 3A: Year 3 Sampling																										d	f			
Task 3B: Year 3 Data mgmt and QA																										d	f			
Task 4: Analysis and interpretation																													d	f

D = Draft deliverable
f = Final deliverable
■ = Activity

Deliverables:

- Task 0: Amended QAPP, including detailed sampling and analysis plan
- Tasks 1A, 2A, and 3A: Year- end monitoring reports by USGS and AHPL
- Tasks 1B, 2B, 3B: QA Officer Memo, data uploaded to CEDEN
- Task 4: Detailed interpretive report including findings of 3-year sampling program and recommendations for future monitoring

Note: Option B (hybrid design) looks similar but adds a 4th year of monitoring from Oct. 2021 – Sept. 2022 and delays interpretive report by 1 year to 2023.

Budget and Principal Investigators

The budget for proposed monitoring in Table 11 below covers year 1 of the proposed 4-year study.

Table 12 shows a multi-year planning budget. Note that the Option B extends over 4 years of monitoring. Even though monitoring activities remain essentially the same from year to year, we assumed a cost escalation of 3% per year. We also assume that the Option B data analysis and interpretation would require somewhat more effort, as it involves analyzing two classes of data from separate sampling designs, and could include an analysis of pesticide and toxicity trends over time. The average annual cost of Option A (not adjusted for inflation) is $218K per year, while Option B averages $238K per year.

Participants in the study include:

- San Francisco Estuary Institute – Aquatic Science Center (ASC)
- Aquatic Health Program Laboratory at UC Davis (AHPL)
- U.S. Geological Survey Organic Chemistry Research Laboratory (OCRL)
- USGS National Water Quality Laboratory (NWQL)

All field work will be done by staff of the USGS OCRL at Sacramento State. They will also perform the pesticides chemical analyses. The USGS lab has a unique capability to test 170+ analytes, low detection limits, and a competitive cost when compared to commercial labs. In addition, the USGS has offered a 10% cost share on labor and travel. Water samples will be processed and analyzed by liquid chromatography tandem mass spectrometry (LC/MSMS) or gas chromatography mass spectrometry (GC/MS). These analysis methods are documented in a series of USGS reports and have been previously described in the Delta RMP's FY15/16 data report. See Appendix 1 for the planned analysis method for each analyte.

USGS OCRL will produce an informal data report for the Delta RMP. After some discussion, the project PI and staff agreed it was not worth the extra effort and expense to produce a formal USGS Open File Report, as we did in Years 1 and 2. A report like this would not add a great deal of new information to the literature. Further, a formal report would be less timely, as it typically takes several extra months to publish due to the USGS' editing and approval process. The report will contain describe sample collection and analysis methods, monitoring results, and a summary of data quality assurance.

Toxicity analyses are funded as an in-kind contribution by the State Water Resources Control Board, through the SWAMP program. SWAMP has a contract with AHPL, the UC Davis toxicity lab, which covers toxicity testing and reporting of results, but nothing else. In the past, lab staff have provided us with a number of *pro bono* "extras," such as participation in meetings, presentations of preliminary results, and a detailed year-end report. The contract manager at SWAMP has indicated that they are not willing to pay for these extras under their contract, which is to cover lab analyses only. If we would like to continue having these extra services, we will need to pay for them out of the Delta RMP budget.

The estimated cost of these extra services from AHPL is $15,063. This covers preparing and sending provisional data and information on the labs internal processes and controls, in addition to having the lab manager attend Delta RMP meetings to give updates. Note that we have not budgeted for a formal year-end report as in years past in order to reduce costs. However, the lab manager understands that there may be substantive comments on the data, and that staff may need to prepare a detailed response to comments and make revisions to deliverables.

The first task in the list should be considered essential. Provisional results of toxicity testing is required for the Delta RMP TAC to identify samples on which to perform TIEs.

The budget for data management and quality assurance is $40,998, as shown in Table 11. This budget is somewhat more than was budgeted in years 1 and 2 of Delta RMP pesticides monitoring, but more in line with actual expenses. This task was budgeted in FY16/17 at $37,400 and projected to go over budget by approximately $5,000. The previous budgets were not adequate for the task. In brief, we encountered problems with missing and incorrect data that has required a great deal of troubleshooting and correspondence with the labs. In addition, some work has had to be repeated with corrected data, for example the database queries that we run as a part of the QA process. For this proposal, the level of effort and budgets have been adjusted to meet these expectations. ASC and USGS have assessed the “lessons learned” from the first two years of CUP monitoring and are confident that previous data management challenges will be minimized.

Table 11 Budget for proposed Delta RMP Monitoring of Current-Use Pesticides and Toxicity

Contractor	Item	Number	Unit Cost	Option A Cost	Option B Cost
USGS	**Field sample collection and lab analysis**				
	Project oversight and reporting			$19,350	$19,350
	Sample collection, labor			$22,659	$30,993
	Sample collection, supplies			$7,445	$7,445
	GC/MS Analyses			$82,587	$82,587
	LC/MS/MS Analyses			$59,804	$59,804
	NWQL Analyses			$11,025	$11,025
	Reports			$6,691	$6,691
	USGS Cost share (10% of labor and travel			-$17,269	-$18,022
				$217,645	**$192,292**
AHPL	**Toxicity Reporting**				
	Provisional Data				
	A) SWAMP Toxicity Transformers (no charge)	6	0	$0	
	B) Bench Sheet Copies	6	$500	$3,000	
	C) Reference Toxicant Control Charts	6	$875	$5,250	
	D) Corrective Actions Table	6	$100	$600	
	Attend meetings and present preliminary results	4	$800	$3,200	
	Indirect costs (University mandated 25%)			$3,013	
				$15,063	**$15,063**
ASC	**Data Management and Quality Assurance**				
	DS Project Management and Coordination	70	$115	$6,900	
	Data Receipt and Data Management	193	$105	$16,485	
	Data Validation	88	$152	$7,904	
	Data Storage and Release	46	$100	$4,600	
	Toxicity data QA Summary	10	$152	$1,520	
	10% contingency			$3,589	
				$40,998	**$40,998**
			Total	**$248,352** (Option A)	**$255,933** (Option B)

Toxicity Analysis Budget (in-kind contribution by SWAMP)

AHPL	Toxicity Lab Analysis	Number	Unit Cost	Total Cost
	Ceriodaphnia 7-day test	60	$1,160	$69,600
	Hyalella 10-day test	60	$1,160	$69,600
	Selenastrum (algae) 96-hr test	60	$960	$57,600
	Chironomus (midge larvae) 10-day test	60	$1,160	$69,600
	Pimephales (fathead minnow) 7-day test	60	$1,200	$72,000
				$270,720
	Toxicity Identification Evaluations (TIEs)*			
	Phase I TIE	4	$6,600	$26,400
	Phase II TIE	1	$14,000	$14,000
				$40,400
	Toxicity testing total (same for Option A & B)			**$311,120**

*May not be necessary, pending results of initial toxicity testing

Table 12 Multi-year planning budget for pesticides and toxicity monitoring in the Delta.

Item	Option A	Option B
Year 1 Monitoring	$250K	$256K
Year 2 Monitoring	$258K	$264K
Year 3 Monitoring	$265K	$272K
Year 4 monitoring	-	$280K
Interpretive Report	$100K	$120K
Project Total	**$873K**	**$1,190K**

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Appendix 1 Water Quality Measurements, Methods and Reporting Limits

In Table 13 below, methods are referred to by the following codes.

1	Hladik, M.L., Smalling, K.L., and Kuivila, K.M., 2009, Methods of analysis—Determination of pyrethroid insecticides in water and sediment using gas chromatography/mass spectrometry: U.S. Geological Survey Techniques and Methods 5–C2, 18 p. https://pubs.usgs.gov/tm/tm5c2/tm5c2.pdf
2	Hladik, M.L., Smalling, K.L., and Kuivila, K.M., 2008, A multi-residue method for the analysis of pesticides and pesticide degradates in water using Oasis HLB solid phase extraction and gas chromatography-ion trap mass spectrometry: Bulletin of Environmental Contamination and Toxicology, v. 80, p. 139–144.
3	Hladik, M.L., and Calhoun, D.L., 2012, Analysis of the herbicide diuron, three diuron degradates, and six neonicotinoid insecticides in water—Method details and application to two Georgia streams: U.S. Geological Survey Scientific Investigations Report 2012–5206, 10 p. https://pubs.usgs.gov/sir/2012/5206/pdf/sir20125206.pdf
4	Hladik, M.L., and McWayne, M.M., 2012, Methods of analysis—Determination of pesticides in sediment using gas chromatography/mass spectrometry: U.S. Geological Survey Techniques and Methods 5–C3, 18 p. Available at http://pubs.usgs.gov/tm/tm5c3
EPA 440	Zimmerman, C. F., Keefe, C. W., Bashe, J. 1997. Method 440.0 Determination of Carbon and Nitrogen in Sediments and Particulates of Estuarine/Coastal Waters Using Elemental Analysis. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/00. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=309418
NFM-A6	Chapter A6, *Field Measurements* in: Wilde, F. D., D. B. Radtke, Jacob Gibs, and R. T. Iwatsubo. *National Field Manual for the Collection of Water-Quality Data: US Geological Survey Techniques of Water-Resources Investigations*. Handbooks for Water-Resources Investigations, Book 9. Reston, VA: U.S. Geological Survey, 2005. https://water.usgs.gov/owq/FieldManual/.
OFR-92-480	Brenton, R.W., Arnett, T.L. 1993. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory--Determination of dissolved organic carbon by UV-promoted persulfate oxidation and infrared spectrometry: U.S. Geological Survey Open-File Report 92-480, 12 p. https://nwql.usgs.gov/rpt.shtml?OFR-92-480
SM […]	Rice, E.W., R.B. Baird, A.D. Eaton, and L.S. Clesceri. *Standard Methods for the Examination of Water and Wastewater*. Water Environmental Federation, American Water Works Association, American Public Health Association, 2005. https://www.standardmethods.org/

The numbers and letters after "SM" refer to the method number in *Standard Methods*. Readers are referred to either the print edition, or individual chapters can be purchased online.

TM-5-B1 Garbarino, J.R., Kanagy, L.K., Cree, M.E. 2006. Determination of Elements in Natural Water, Biota, Sediment and Soil Samples Using Collision/Reaction Cell Inductively Coupled Plasma-Mass Spectrometry, U.S. Geological Survey Techniques and Methods, 88p. (Book 5, Sec. B, Chap.1). https://pubs.usgs.gov/tm/2006/tm5b1/

Table 13 Summary of method, Reporting Limits (RL) and Method Detection Limits (MDL) for monitored constituents.

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Oxygen, Dissolved	Water	Field Parameters	0.5	0.5	mg/L	USGS Field crew		NFM-A6		
pH	Water	Field Parameters	NA	NA	NA	USGS Field crew		NFM-A6		
Specific Conductivity	Water	Field Parameters	10.0	10.0	uS/cm	USGS Field crew		NFM-A6		
Temperature	Water	Field Parameters	NA	NA	NA	USGS Field crew		NFM-A6		
Turbidity	Water	Field Parameters	1.0	1.0	FNU	USGS Field crew		NFM-A6		
Alkalinity as $CaCO_3$	Water	Conventional	12.0	4.0	mg/L	AHPL		SM 2320B		
Ammonia as N	Water	Conventional	0.2	0.1	mg/L	AHPL		SM 4500-NH3F		
Hardness as $CaCO_3$	Water	Conventional	6.0	2.0	mg/L	AHPL		SM 2340C		
Dissolved Organic Carbon	Water	Conventional	0.2	0.2	mg/L	USGS NWQL		OFR-94-480		
Particulate Organic Carbon	Water	Conventional	0.1	0.1	mg/L	USGS NWQL		EPA 440		
Copper, dissolved	Water	Trace Metals	0.8	0.8	ug/L	USGS NWQL		TM-5-B1		
3,4-Dichloroaniline	Water	Herbicide	3.2	3.2	ng/L	OCRL		3	--	--
3,4-Dichloroaniline	Suspended Sediment	Herbicide	8.3	8.3	ng/L	OCRL		2	--	--
3,5-Dichloroaniline	Water	Herbicide	7.6	7.6	ng/L	OCRL		3	--	--
3,5-Dichloroaniline	Suspended Sediment	Herbicide	7.6	7.6	ng/L	OCRL		2	--	--
Acetamiprid	Water	Insecticide	3.3	3.3	ng/L	OCRL		2	2,100	Invertebrates - Chronic
Acetochlor	Water	Herbicide	1.5	1.5	ng/L	OCRL		2	1,430	Nonvascular plants - Acute
Acetochlor	Suspended Sediment	Herbicide	1.5	1.5	ng/L	OCRL		1	1,430	Nonvascular plants - Acute
Acibenzolar-S-methyl	Water	Fungicide	3.0	3.0	ng/L	OCRL		2	--	--
Acibenzolar-S-methyl	Suspended Sediment	Fungicide	3.0	3.0	ng/L	OCRL		2	--	--
Alachlor	Water	Herbicide	1.7	1.7	ng/L	OCRL		2	1,640	Nonvascular plants - Acute
Alachlor	Suspended Sediment	Herbicide	1.7	1.7	ng/L	OCRL	New in 2018	2	1,640	Nonvascular plants - Acute

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Allethrin	Water	Insecticide	1.0	1.0	ng/L	OCRL		2	1,050	Invertebrates - Acute
Allethrin	Suspended Sediment	Insecticide	1.0	1.0	ng/L	OCRL		2	1,050	Invertebrates - Acute
Atrazine	Water	Herbicide	2.3	2.3	ng/L	OCRL		1	1,000	Nonvascular plants - Acute
Atrazine	Suspended Sediment	Herbicide	2.3	2.3	ng/L	OCRL		2	1,000	Nonvascular plants - Acute
Azinphos-methyl	Water	Insecticide	9.4	9.4	ng/L	OCRL		2	80.0	Invertebrates - Acute
Azinphos-methyl	Suspended Sediment	Insecticide	9.4	9.4	ng/L	OCRL		2	80.0	Invertebrates - Acute
Azinphos-methyl oxon	Water	Insecticide	9.4	9.4	ng/L	OCRL		2	11.0	Invertebrates - Chronic
Azinphos-methyl oxon	Suspended Sediment	Insecticide	9.4	9.4	ng/L	OCRL		2	11.0	Invertebrates - Chronic
Azoxystrobin	Water	Fungicide	3.1	3.1	ng/L	OCRL		2	8,000	Invertebrates - Chronic
Azoxystrobin	Suspended Sediment	Fungicide	3.1	3.1	ng/L	OCRL		3	8,000	Invertebrates - Chronic
Benefin (Benfluralin)	Water	Herbicide	2.0	2.0	ng/L	OCRL		2	1,900	Fish - Chronic
Benefin (Benfluralin)	Suspended Sediment	Herbicide	2.0	2.0	ng/L	OCRL		3	1,900	Fish - Chronic
Benzovindiflupyr	Water	Fungicide	3.4	3.4	ng/L	OCRL	New in 2018	3	950	Fish - Chronic
Benzovindiflupyr	Suspended Sediment	Fungicide	3.4	3.4	ng/L	OCRL	New in 2018	2	950	Fish - Chronic
Bifenthrin	Water	Insecticide	0.7	0.7	ng/L	OCRL		2	1.3	Invertebrates - Chronic
Bifenthrin	Suspended Sediment	Insecticide	0.7	0.7	ng/L	OCRL		2	1.3	Invertebrates - Chronic
Boscalid	Water	Fungicide	2.8	2.8	ng/L	OCRL		2	116,000	Fish - Chronic
Boscalid	Suspended Sediment	Fungicide	2.8	2.8	ng/L	OCRL		2	116,000	Fish - Chronic
Bromoconazole	Water	Fungicide	3.2	3.2	ng/L	OCRL		3	--	--
Bromoconazole	Suspended Sediment	Fungicide	3.2	3.2	ng/L	OCRL		2	--	--
Butralin	Water	Herbicide	2.6	2.6	ng/L	OCRL		3	--	--
Butralin	Suspended Sediment	Herbicide	2.6	2.6	ng/L	OCRL		3	--	--
Butylate	Water	Herbicide	1.8	1.8	ng/L	OCRL		2	105,000	Fish - Acute
Butylate	Suspended Sediment	Herbicide	1.8	1.8	ng/L	OCRL		1	105,000	Fish - Acute
Captan	Water	Fungicide	10.2	10.2	ng/L	OCRL		2	105	Invertebrates - Acute
Captan	Suspended Sediment	Fungicide	10.2	10.2	ng/L	OCRL		1	105	Invertebrates - Acute
Carbaryl	Water	Insecticide	6.5	6.5	ng/L	OCRL		3	500	Invertebrates - Chronic
Carbaryl	Suspended Sediment	Insecticide	6.5	6.5	ng/L	OCRL		1	500	Invertebrates - Chronic
Carbendazim	Water	Fungicide	4.2	4.2	ng/L	OCRL		2	990	Fish - Chronic
Carbofuran	Water	Insecticide	3.1	3.1	ng/L	OCRL		2	860	Fish - Chronic
Carbofuran	Suspended Sediment	Insecticide	3.1	3.1	ng/L	OCRL		2	860	Fish - Chronic
Carboxin	Water	Fungicide	4.5	4.5	ng/L	OCRL	New in 2018	3	370,000	Nonvascular plants - Acute

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Chlorantraniliprole	Water	Insecticide	4.0	4.0	ng/L	OCRL		3	6,360,000	Fish - Chronic
Chlorfenapyr	Water	Insecticide	3.3	3.3	ng/L	OCRL	New in 2018	1	20,000	Nonvascular plants - Acute
Chlorfenapyr	Suspended Sediment	Insecticide	3.3	3.3	ng/L	OCRL	New in 2018	3	20,000	Nonvascular plants - Acute
Chlorothalonil	Water	Fungicide	4.1	4.1	ng/L	OCRL		2	2,400	Nonvascular plants - Acute
Chlorothalonil	Suspended Sediment	Fungicide	4.1	4.1	ng/L	OCRL		2	2,400	Nonvascular plants - Acute
Chlorpyrifos	Water	Insecticide	2.1	2.1	ng/L	OCRL		2	800,000	Invertebrates - Chronic
Chlorpyrifos	Suspended Sediment	Insecticide	2.1	2.1	ng/L	OCRL		2	800,000	Invertebrates - Chronic
Chlorpyrifos oxon	Water	Insecticide	5.0	5.0	ng/L	OCRL		2	--	--
Chlorpyrifos oxon	Suspended Sediment	Insecticide	5.0	5.0	ng/L	OCRL		2	--	--
Clomazone	Water	Herbicide	2.5	2.5	ng/L	OCRL		2	167,000	Nonvascular plants - Acute
Clomazone	Suspended Sediment	Herbicide	2.5	2.5	ng/L	OCRL		3	167,000	Nonvascular plants - Acute
Clothianidin	Water	Insecticide	3.9	3.9	ng/L	OCRL		2	1,100	Invertebrates - Chronic
Coumaphos	Water	Insecticide	3.1	3.1	ng/L	OCRL		3	33.7	Invertebrates - Chronic
Coumaphos	Suspended Sediment	Insecticide	3.1	3.1	ng/L	OCRL		2	33.7	Invertebrates - Chronic
Cyantraniliprole	Water	Insecticide	4.2	4.2	ng/L	OCRL		1	6,560	Invertebrates - Chronic
Cyazofamid	Water	Fungicide	4.1	4.1	ng/L	OCRL		3	8,700	Invertebrates - Chronic
Cycloate	Water	Herbicide	1.1	1.1	ng/L	OCRL		2	1,200,000	Invertebrates - Acute
Cycloate	Suspended Sediment	Herbicide	1.1	1.1	ng/L	OCRL		2	1,200,000	Invertebrates - Acute
Cyfluthrin	Water	Insecticide	1.0	1.0	ng/L	OCRL		2	7.4	Invertebrates - Chronic
Cyfluthrin	Suspended Sediment	Insecticide	1.0	1.0	ng/L	OCRL		2	7.4	Invertebrates - Chronic
Cyhalofop-butyl	Water	Herbicide	1.9	1.9	ng/L	OCRL		2	47,400	Invertebrates - Chronic
Cyhalofop-butyl	Suspended Sediment	Herbicide	1.9	1.9	ng/L	OCRL		2	47,400	Invertebrates - Chronic
Cyhalothrin (all isomers)	Water	Insecticide	0.5	0.5	ng/L	OCRL		2	101,000	Fish - Chronic
Cyhalothrin (all isomers)	Suspended Sediment	Insecticide	0.5	0.5	ng/L	OCRL		2	101,000	Fish - Chronic
Cymoxanil	Water	Fungicide	3.9	3.9	ng/L	OCRL		1	--	--
Cypermethrin	Water	Insecticide	1.0	1.0	ng/L	OCRL		2	69.0	Invertebrates - Chronic
Cypermethrin	Suspended Sediment	Insecticide	1.0	1.0	ng/L	OCRL		2	69.0	Invertebrates - Chronic
Cyproconazole	Water	Fungicide	4.7	4.7	ng/L	OCRL		2	--	--
Cyproconazole	Suspended Sediment	Fungicide	4.7	4.7	ng/L	OCRL		2	--	--
Cyprodinil	Water	Fungicide	7.4	7.4	ng/L	OCRL		2	11.0	Invertebrates - Chronic
Cyprodinil	Suspended Sediment	Fungicide	7.4	7.4	ng/L	OCRL		3	11.0	Invertebrates - Chronic

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
DCPA	Water	Herbicide	2.0	2.0	ng/L	OCRL		2	110	Invertebrates - Chronic
DCPA	Suspended Sediment	Herbicide	2.0	2.0	ng/L	OCRL		2	110	Invertebrates - Chronic
DCPMU	Water	Herbicide	3.5	3.5	ng/L	OCRL		2	37.0	Invertebrates - Chronic
DCPU	Water	Herbicide	3.4	3.4	ng/L	OCRL		2	3,000,000	Invertebrates - Chronic
Deltamethrin	Water	Insecticide	0.6	0.6	ng/L	OCRL		2	4.1	Invertebrates - Chronic
Deltamethrin	Suspended Sediment	Insecticide	0.6	0.6	ng/L	OCRL		2	4.1	Invertebrates - Chronic
Desthio-prothioconazole	Water	Fungicide	3.0	3.0	ng/L	OCRL		2	--	--
Desulfinylfipronil	Water	Insecticide	1.6	1.6	ng/L	OCRL		2	590	Fish - Chronic
Desulfinylfipronil	Suspended Sediment	Insecticide	1.6	1.6	ng/L	OCRL		3	590	Fish - Chronic
Desulfinylfipronil amide	Water	Insecticide	3.2	3.2	ng/L	OCRL		3	--	--
Desulfinylfipronil amide	Suspended Sediment	Insecticide	3.2	3.2	ng/L	OCRL		2	--	--
Diazinon	Water	Insecticide	0.9	0.9	ng/L	OCRL		2	105	Invertebrates - Acute
Diazinon	Suspended Sediment	Insecticide	0.9	0.9	ng/L	OCRL		2	105	Invertebrates - Acute
Diazoxon	Water	Insecticide	5.0	5.0	ng/L	OCRL		2	--	--
Diazoxon	Suspended Sediment	Insecticide	5.0	5.0	ng/L	OCRL		2	--	--
Dichlorvos	Water	Insecticide	5.1	5.1	ng/L	OCRL	New in 2018	2	5.8	Invertebrates - Chronic
Dichlorvos	Suspended Sediment	Insecticide	5.1	5.1	ng/L	OCRL	New in 2018	3	5.8	Invertebrates - Chronic
Difenoconazole	Water	Fungicide	10.5	10.5	ng/L	OCRL		3	860	Fish - Chronic
Difenoconazole	Suspended Sediment	Fungicide	10.5	10.5	ng/L	OCRL		2	860	Fish - Chronic
Dimethomorph	Water	Fungicide	6.0	6.0	ng/L	OCRL		2	110,000	Invertebrates - Chronic
Dimethomorph	Suspended Sediment	Fungicide	6.0	6.0	ng/L	OCRL		2	110,000	Invertebrates - Chronic
Dinotefuran	Water	Insecticide	4.5	4.5	ng/L	OCRL		2	480,000	Fish - Chronic
Dithiopyr	Water	Herbicide	1.6	1.6	ng/L	OCRL		2	--	--
Dithiopyr	Suspended Sediment	Herbicide	1.6	1.6	ng/L	OCRL		2	--	--
Diuron	Water	Herbicide	3.2	3.2	ng/L	OCRL		2	2,400	Nonvascular plants - Acute
EPTC	Water	Herbicide	1.5	1.5	ng/L	OCRL		3	800,000	Invertebrates - Chronic
EPTC	Suspended Sediment	Herbicide	1.5	1.5	ng/L	OCRL		2	800,000	Invertebrates - Chronic
Esfenvalerate	Water	Insecticide	0.5	0.5	ng/L	OCRL		2	--	--
Esfenvalerate	Suspended Sediment	Insecticide	0.5	0.5	ng/L	OCRL		2	--	--
Ethaboxam	Water	Fungicide	3.8	3.8	ng/L	OCRL		2	7,000	Nonvascular plants - Acute
Ethalfluralin	Water	Herbicide	3.0	3.0	ng/L	OCRL		3	--	--
Ethalfluralin	Suspended Sediment	Herbicide	3.0	3.0	ng/L	OCRL		2	--	--

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Etofenprox	Water	Insecticide	2.2	2.2	ng/L	OCRL		2	10.0	Invertebrates - Chronic
Etofenprox	Suspended Sediment	Insecticide	2.2	2.2	ng/L	OCRL		2	10.0	Invertebrates - Chronic
Etoxazole	Water	Insecticide	4.2	4.2	ng/L	OCRL	New in 2018	2	130	Invertebrates - Chronic
Etoxazole	Suspended Sediment	Insecticide	4.2	4.2	ng/L	OCRL	New in 2018	2	130	Invertebrates - Chronic
Famoxadone	Water	Fungicide	2.5	2.5	ng/L	OCRL		2	75,000	Invertebrates - Chronic
Famoxadone	Suspended Sediment	Fungicide	2.5	2.5	ng/L	OCRL		3	75,000	Invertebrates - Chronic
Fenamidone	Water	Fungicide	5.1	5.1	ng/L	OCRL		2	4,700	Fish - Chronic
Fenamidone	Suspended Sediment	Fungicide	5.1	5.1	ng/L	OCRL		3	4,700	Fish - Chronic
Fenarimol	Water	Fungicide	6.5	6.5	ng/L	OCRL		2	120,000	Invertebrates - Acute
Fenarimol	Suspended Sediment	Fungicide	6.5	6.5	ng/L	OCRL		2	120,000	Invertebrates - Acute
Fenbuconazole	Water	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Fenbuconazole	Suspended Sediment	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Fenhexamid	Water	Fungicide	7.6	7.6	ng/L	OCRL		2	101,000	Fish - Chronic
Fenhexamid	Suspended Sediment	Fungicide	7.6	7.6	ng/L	OCRL		2	101,000	Fish - Chronic
Fenpropathrin	Water	Insecticide	0.6	0.6	ng/L	OCRL		2	60.0	Fish - Chronic
Fenpropathrin	Suspended Sediment	Insecticide	0.6	0.6	ng/L	OCRL		3	60.0	Fish - Chronic
Fenpyroximate	Water	Insecticide	5.2	5.2	ng/L	OCRL		2	16.0	Fish - Chronic
Fenpyroximate	Suspended Sediment	Insecticide	5.2	5.2	ng/L	OCRL		2	16.0	Fish - Chronic
Fenthion	Water	Insecticide	5.5	5.5	ng/L	OCRL		3	13.0	Invertebrates - Chronic
Fenthion	Suspended Sediment	Insecticide	5.5	5.5	ng/L	OCRL		1	13.0	Invertebrates - Chronic
Fipronil	Water	Insecticide	2.9	2.9	ng/L	OCRL		1	100,000	Invertebrates - Chronic
Fipronil	Suspended Sediment	Insecticide	2.9	2.9	ng/L	OCRL		2	100,000	Invertebrates - Chronic
Fipronil sulfide	Water	Insecticide	1.8	1.8	ng/L	OCRL		2	110	Invertebrates - Chronic
Fipronil sulfide	Suspended Sediment	Insecticide	1.8	1.8	ng/L	OCRL		2	110	Invertebrates - Chronic
Fipronil sulfone	Water	Insecticide	3.5	3.5	ng/L	OCRL		2	37.0	Invertebrates - Chronic
Fipronil sulfone	Suspended Sediment	Insecticide	3.5	3.5	ng/L	OCRL		2	37.0	Invertebrates - Chronic
Flonicamid	Water	Insecticide	3.4	3.4	ng/L	OCRL		2	3,000,000	Invertebrates - Chronic
Fluazinam	Water	Fungicide	4.4	4.4	ng/L	OCRL		2	6,300	Invertebrates - Chronic
Fluazinam	Suspended Sediment	Fungicide	4.4	4.4	ng/L	OCRL		2	6,300	Invertebrates - Chronic
Flubendiamide	Water	Insecticide	6.2	6.2	ng/L	OCRL	New in 2018	2	140	Invertebrates - Acute
Flubendiamide	Suspended Sediment	Insecticide	6.2	6.2	ng/L	OCRL	New in 2018	2	140	Invertebrates - Acute
Fludioxonil	Water	Fungicide	7.3	7.3	ng/L	OCRL		2	1,000	Invertebrates - Chronic

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Fludioxonil	Suspended Sediment	Fungicide	7.3	7.3	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Flufenacet	Water	Herbicide	4.7	4.7	ng/L	OCRL		2	--	--
Flufenacet	Suspended Sediment	Herbicide	4.7	4.7	ng/L	OCRL		2	--	--
Flumetralin	Water	Other	5.8	5.8	ng/L	OCRL		2	830,000	Nonvascular plants - Acute
Flumetralin	Suspended Sediment	Other	5.8	5.8	ng/L	OCRL		1	830,000	Nonvascular plants - Acute
Fluopicolide	Water	Fungicide	3.9	3.9	ng/L	OCRL		2	1,100,000	Fish - Chronic
Fluopicolide	Suspended Sediment	Fungicide	3.9	3.9	ng/L	OCRL		2	1,100,000	Fish - Chronic
Fluopyram	Water	Fungicide	3.8	3.8	ng/L	OCRL	New in 2018	3	--	--
Fluopyram	Suspended Sediment	Fungicide	3.8	3.8	ng/L	OCRL	New in 2018	1	--	--
Fluoxastrobin	Water	Fungicide	9.5	9.5	ng/L	OCRL		2	13,000	Vascular plants - Acute
Fluoxastrobin	Suspended Sediment	Fungicide	9.5	9.5	ng/L	OCRL		3	13,000	Vascular plants - Acute
Flupyradifurone	Water	Insecticide	3.0	3.0	ng/L	OCRL	New in 2018	2	5,200	Nonvascular plants - Acute
Fluridone	Water	Herbicide	3.7	3.7	ng/L	OCRL		2	480,000	Fish - Chronic
Flusilazole	Water	Fungicide	4.5	4.5	ng/L	OCRL		1	290	Nonvascular plants - Acute
Flusilazole	Suspended Sediment	Fungicide	4.5	4.5	ng/L	OCRL		2	290	Nonvascular plants - Acute
Flutolanil	Water	Fungicide	4.4	4.4	ng/L	OCRL		2	220,000	Fish - Chronic
Flutolanil	Suspended Sediment	Fungicide	4.4	4.4	ng/L	OCRL		1	220,000	Fish - Chronic
Flutriafol	Water	Fungicide	4.2	4.2	ng/L	OCRL		3	310,000	Invertebrates - Chronic
Flutriafol	Suspended Sediment	Fungicide	4.2	4.2	ng/L	OCRL		3	310,000	Invertebrates - Chronic
Fluxapyroxad	Water	Fungicide	4.8	4.8	ng/L	OCRL		3	--	--
Fluxapyroxad	Suspended Sediment	Fungicide	4.8	4.8	ng/L	OCRL		3	--	--
Hexazinone	Water	Herbicide	8.4	8.4	ng/L	OCRL		3	7,000	Nonvascular plants - Acute
Hexazinone	Suspended Sediment	Herbicide	8.4	8.4	ng/L	OCRL		2	7,000	Nonvascular plants - Acute
Imazalil	Water	Fungicide	10.5	10.5	ng/L	OCRL		2	--	--
Imazalil	Suspended Sediment	Fungicide	10.5	10.5	ng/L	OCRL		3	--	--
Imidacloprid	Water	Insecticide	3.8	3.8	ng/L	OCRL		2	5,200	Nonvascular plants - Acute
Imidacloprid urea	Water	Insecticide	4.0	4.0	ng/L	OCRL	New in 2018	2	3,000	Vascular plants - Acute
Indoxacarb	Water	Insecticide	4.9	4.9	ng/L	OCRL		2	75,000	Invertebrates - Chronic
Indoxacarb	Suspended Sediment	Insecticide	4.9	4.9	ng/L	OCRL		2	75,000	Invertebrates - Chronic
Ipconazole	Water	Fungicide	7.8	7.8	ng/L	OCRL		3	180,000	Fish - Chronic
Ipconazole	Suspended Sediment	Fungicide	7.8	7.8	ng/L	OCRL		2	180,000	Fish - Chronic
Iprodione	Water	Fungicide	4.4	4.4	ng/L	OCRL		2	120,000	Invertebrates - Acute
Iprodione	Suspended Sediment	Fungicide	4.4	4.4	ng/L	OCRL		2	120,000	Invertebrates - Acute

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Isofetamid	Water	Fungicide	2.0	2.0	ng/L	OCRL	New in 2018	2	86,000	Fish - Chronic
Isofetamid	Suspended Sediment	Fungicide	2.0	2.0	ng/L	OCRL	New in 2018	2	86,000	Fish - Chronic
Kresoxim-methyl	Water	Fungicide	4.0	4.0	ng/L	OCRL		3	299,200	Vascular plants - Acute
Kresoxim-methyl	Suspended Sediment	Fungicide	4.0	4.0	ng/L	OCRL		2	299,200	Vascular plants - Acute
Malaoxon	Water	Insecticide	5.0	5.0	ng/L	OCRL		3	--	--
Malaoxon	Suspended Sediment	Insecticide	5.0	5.0	ng/L	OCRL		2	--	--
Malathion	Water	Insecticide	3.7	3.7	ng/L	OCRL		2	49.0	Invertebrates - Acute
Malathion	Suspended Sediment	Insecticide	3.7	3.7	ng/L	OCRL		2	49.0	Invertebrates - Acute
Mandipropamid	Water	Fungicide	3.3	3.3	ng/L	OCRL		1	30,000	Invertebrates - Chronic
Metalaxyl	Water	Fungicide	5.1	5.1	ng/L	OCRL		2	1,500	Invertebrates - Chronic
Metalaxyl	Suspended Sediment	Fungicide	5.1	5.1	ng/L	OCRL		2	1,500	Invertebrates - Chronic
Metconazole	Water	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Metconazole	Suspended Sediment	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Methidathion	Water	Insecticide	7.2	7.2	ng/L	OCRL		2	1,040	Nonvascular plants - Acute
Methidathion	Suspended Sediment	Insecticide	7.2	7.2	ng/L	OCRL		2	1,040	Nonvascular plants - Acute
Methoprene	Water	Insecticide	6.4	6.4	ng/L	OCRL		1	9,100	Fish - Chronic
Methoprene	Suspended Sediment	Insecticide	6.4	6.4	ng/L	OCRL		2	9,100	Fish - Chronic
Methoxyfenozide	Water	Insecticide	2.7	2.7	ng/L	OCRL		2	299,200	Vascular plants - Acute
Methyl parathion	Water	Insecticide	3.4	3.4	ng/L	OCRL		2	21,000	Nonvascular plants - Acute
Methyl parathion	Suspended Sediment	Insecticide	3.4	3.4	ng/L	OCRL		2	21,000	Nonvascular plants - Acute
Metolachlor	Water	Herbicide	1.5	1.5	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Metolachlor	Suspended Sediment	Herbicide	1.5	1.5	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Molinate	Water	Herbicide	3.2	3.2	ng/L	OCRL		3	105,000	Fish - Acute
Molinate	Suspended Sediment	Herbicide	3.2	3.2	ng/L	OCRL		2	105,000	Fish - Acute
Myclobutanil	Water	Fungicide	6.0	6.0	ng/L	OCRL		3	830,000	Nonvascular plants - Acute
Myclobutanil	Suspended Sediment	Fungicide	6.0	6.0	ng/L	OCRL		3	830,000	Nonvascular plants - Acute
Napropamide	Water	Herbicide	8.2	8.2	ng/L	OCRL		2	20,000	Fish - Chronic
Napropamide	Suspended Sediment	Herbicide	8.2	8.2	ng/L	OCRL		2	20,000	Fish - Chronic
Novaluron	Water	Insecticide	2.9	2.9	ng/L	OCRL		2	30.0	Invertebrates - Chronic
Novaluron	Suspended Sediment	Insecticide	2.9	2.9	ng/L	OCRL		2	30.0	Invertebrates - Chronic
Oryzalin	Water	Herbicide	5.0	5.0	ng/L	OCRL		2	13,000	Fish - Chronic
Oxadiazon	Water	Herbicide	2.1	2.1	ng/L	OCRL		3	5,200	Nonvascular plants - Acute

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Oxadiazon	Suspended Sediment	Herbicide	2.1	2.1	ng/L	OCRL		2	5,200	Nonvascular plants - Acute
Oxathiapiprolin	Water	Fungicide	3.2	3.2	ng/L	OCRL	New in 2018	3	140,000	Nonvascular plants - Acute
Oxyfluorfen	Water	Herbicide	3.1	3.1	ng/L	OCRL		3	2,240	Nonvascular plants - Acute
Oxyfluorfen	Suspended Sediment	Herbicide	3.1	3.1	ng/L	OCRL		2	2,240	Nonvascular plants - Acute
p,p'-DDD	Water	Insecticide	4.1	4.1	ng/L	OCRL		1	--	--
p,p'-DDD	Suspended Sediment	Insecticide	4.1	4.1	ng/L	OCRL		2	--	--
p,p'-DDE	Water	Insecticide	3.6	3.6	ng/L	OCRL		1	--	--
p,p'-DDE	Suspended Sediment	Insecticide	3.6	3.6	ng/L	OCRL		3	--	--
p,p'-DDT	Water	Insecticide	4.0	4.0	ng/L	OCRL		1	--	--
p,p'-DDT	Suspended Sediment	Insecticide	4.0	4.0	ng/L	OCRL		2	--	--
Paclobutrazol	Water	Fungicide	6.2	6.2	ng/L	OCRL		2	8,000	Vascular plants - Acute
Paclobutrazol	Suspended Sediment	Fungicide	6.2	6.2	ng/L	OCRL		2	8,000	Vascular plants - Acute
Pebulate	Water	Herbicide	2.3	2.3	ng/L	OCRL		3	230,000	Nonvascular plants - Acute
Pebulate	Suspended Sediment	Herbicide	2.3	2.3	ng/L	OCRL		3	230,000	Nonvascular plants - Acute
Pendimethalin	Water	Herbicide	2.3	2.3	ng/L	OCRL		1	5,200	Nonvascular plants - Acute
Pendimethalin	Suspended Sediment	Herbicide	2.3	2.3	ng/L	OCRL		3	5,200	Nonvascular plants - Acute
Penoxsulam	Water	Herbicide	3.5	3.5	ng/L	OCRL		2	3,000	Vascular plants - Acute
Pentachloroanisole	Water	Insecticide	4.7	4.7	ng/L	OCRL		2	190,000	Invertebrates - Chronic
Pentachloroanisole	Suspended Sediment	Insecticide	4.7	4.7	ng/L	OCRL		2	190,000	Invertebrates - Chronic
Pentachloronitrobenzene	Water	Fungicide	3.1	3.1	ng/L	OCRL		2	13,000	Fish - Chronic
Pentachloronitrobenzene	Suspended Sediment	Fungicide	3.1	3.1	ng/L	OCRL		2	13,000	Fish - Chronic
Penthiopyrad	Water	Fungicide	3.2	3.2	ng/L	OCRL	New in 2018	2	100,000	Fish - Chronic
Permethrin	Water	Insecticide	0.6	0.6	ng/L	OCRL		2	42,000	Invertebrates - Chronic
Permethrin	Suspended Sediment	Insecticide	0.6	0.6	ng/L	OCRL		3	42,000	Invertebrates - Chronic
Phenothrin	Water	Insecticide	1.0	1.0	ng/L	OCRL		2	470	Invertebrates - Chronic
Phenothrin	Suspended Sediment	Insecticide	1.0	1.0	ng/L	OCRL		3	470	Invertebrates - Chronic
Phosmet	Water	Insecticide	4.4	4.4	ng/L	OCRL		2	17,500	Invertebrates - Acute
Phosmet	Suspended Sediment	Insecticide	4.4	4.4	ng/L	OCRL		1	17,500	Invertebrates - Acute
Picoxystrobin	Water	Fungicide	4.2	4.2	ng/L	OCRL		3	1,000	Invertebrates - Chronic
Picoxystrobin	Suspended Sediment	Fungicide	4.2	4.2	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Piperonyl butoxide	Water	Other	2.3	2.3	ng/L	OCRL		2	30,000	Invertebrates - Chronic
Piperonyl butoxide	Suspended Sediment	Other	2.3	2.3	ng/L	OCRL		2	30,000	Invertebrates - Chronic

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Prodiamine	Water	Herbicide	5.2	5.2	ng/L	OCRL		2	1,500	Invertebrates - Chronic
Prodiamine	Suspended Sediment	Herbicide	5.2	5.2	ng/L	OCRL		2	1,500	Invertebrates - Chronic
Prometon	Water	Herbicide	2.5	2.5	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Prometon	Suspended Sediment	Herbicide	2.5	2.5	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Prometryn	Water	Herbicide	1.8	1.8	ng/L	OCRL		2	1,040	Nonvascular plants - Acute
Prometryn	Suspended Sediment	Herbicide	1.8	1.8	ng/L	OCRL		1	1,040	Nonvascular plants - Acute
Propanil	Water	Herbicide	10.1	10.1	ng/L	OCRL		2	9,100	Fish - Chronic
Propanil	Suspended Sediment	Herbicide	10.1	10.1	ng/L	OCRL		2	9,100	Fish - Chronic
Propargite	Water	Insecticide	6.1	6.1	ng/L	OCRL		2	7,000	Invertebrates - Acute
Propargite	Suspended Sediment	Insecticide	6.1	6.1	ng/L	OCRL		2	7,000	Invertebrates - Acute
Propiconazole	Water	Fungicide	5.0	5.0	ng/L	OCRL		2	21,000	Nonvascular plants - Acute
Propiconazole	Suspended Sediment	Fungicide	5.0	5.0	ng/L	OCRL		3	21,000	Nonvascular plants - Acute
Propyzamide	Water	Herbicide	5.0	5.0	ng/L	OCRL		2	224,000	Fish - Chronic
Propyzamide	Suspended Sediment	Herbicide	5.0	5.0	ng/L	OCRL		2	224,000	Fish - Chronic
Pyraclostrobin	Water	Fungicide	2.9	2.9	ng/L	OCRL		2	1,500	Nonvascular plants - Acute
Pyraclostrobin	Suspended Sediment	Fungicide	2.9	2.9	ng/L	OCRL		2	1,500	Nonvascular plants - Acute
Pyridaben	Water	Insecticide	5.4	5.4	ng/L	OCRL		2	2,760	Invertebrates - Chronic
Pyridaben	Suspended Sediment	Insecticide	5.4	5.4	ng/L	OCRL		2	2,760	Invertebrates - Chronic
Pyrimethanil	Water	Fungicide	4.1	4.1	ng/L	OCRL		2	20,000	Fish - Chronic
Pyrimethanil	Suspended Sediment	Fungicide	4.1	4.1	ng/L	OCRL		2	20,000	Fish - Chronic
Pyriproxyfen	Water	Other	5.2	5.2	ng/L	OCRL	New in 2018	3	15.0	Invertebrates - Chronic
Pyriproxyfen	Suspended Sediment	Other	5.2	5.2	ng/L	OCRL	New in 2018	3	15.0	Invertebrates - Chronic
Quinoxyfen	Water	Fungicide	3.3	3.3	ng/L	OCRL		2	13,000	Fish - Chronic
Quinoxyfen	Suspended Sediment	Fungicide	3.3	3.3	ng/L	OCRL		2	13,000	Fish - Chronic
Resmethrin	Water	Insecticide	1.0	1.0	ng/L	OCRL		2	140	Fish - Acute
Resmethrin	Suspended Sediment	Insecticide	1.0	1.0	ng/L	OCRL		2	140	Fish - Acute
Sedaxane	Water	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Sedaxane	Suspended Sediment	Fungicide	5.2	5.2	ng/L	OCRL		2	--	--
Simazine	Water	Herbicide	5.0	5.0	ng/L	OCRL		3	2,240	Nonvascular plants - Acute
Simazine	Suspended Sediment	Herbicide	5.0	5.0	ng/L	OCRL		3	2,240	Nonvascular plants - Acute
Sulfoxaflor	Water	Insecticide	4.4	4.4	ng/L	OCRL	New in 2018	2	24,500	Invertebrates - Acute
tau-Fluvalinate	Water	Insecticide	0.7	0.7	ng/L	OCRL		2	64.0	Fish - Chronic
tau-Fluvalinate	Suspended Sediment	Insecticide	0.7	0.7	ng/L	OCRL		2	64.0	Fish - Chronic

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Tebuconazole	Water	Fungicide	3.7	3.7	ng/L	OCRL		2	11,000	Fish - Chronic
Tebuconazole	Suspended Sediment	Fungicide	3.7	3.7	ng/L	OCRL		2	11,000	Fish - Chronic
Tebufenozide	Water	Insecticide	3.0	3.0	ng/L	OCRL	New in 2018	2	29,000	Invertebrates - Chronic
Tebupirimfos	Water	Insecticide	1.9	1.9	ng/L	OCRL		2	299,200	Vascular plants - Acute
Tebupirimfos	Suspended Sediment	Insecticide	1.9	1.9	ng/L	OCRL		3	299,200	Vascular plants - Acute
Tebupirimfos oxon	Water	Insecticide	2.8	2.8	ng/L	OCRL		2	--	--
Tebupirimfos oxon	Suspended Sediment	Insecticide	2.8	2.8	ng/L	OCRL		2	--	--
Tefluthrin	Water	Insecticide	0.6	0.6	ng/L	OCRL		2	4.0	Fish - Chronic
Tefluthrin	Suspended Sediment	Insecticide	0.6	0.6	ng/L	OCRL		2	4.0	Fish - Chronic
Tetraconazole	Water	Fungicide	5.6	5.6	ng/L	OCRL		3	190,000	Invertebrates - Chronic
Tetraconazole	Suspended Sediment	Fungicide	5.6	5.6	ng/L	OCRL		2	190,000	Invertebrates - Chronic
Tetradifon	Water	Insecticide	3.8	3.8	ng/L	OCRL		2	--	--
Tetradifon	Suspended Sediment	Insecticide	3.8	3.8	ng/L	OCRL		2	--	--
Tetramethrin	Water	Insecticide	0.5	0.5	ng/L	OCRL		2	1,850	Fish - Acute
Tetramethrin	Suspended Sediment	Insecticide	0.5	0.5	ng/L	OCRL		2	1,850	Fish - Acute
Thiabendazole	Water	Fungicide	3.6	3.6	ng/L	OCRL		2	42,000	Invertebrates - Chronic
Thiacloprid	Water	Insecticide	3.2	3.2	ng/L	OCRL		3	970	Invertebrates - Chronic
Thiamethoxam	Water	Insecticide	3.4	3.4	ng/L	OCRL		2	17,500	Invertebrates - Acute
Thiamethoxam Degradate (CGA-355190)	Water	Insecticide	3.5	3.5	ng/L	OCRL	New in 2018	3	--	--
Thiamethoxam Degradate (NOA-407475)	Water	Insecticide	3.4	3.4	ng/L	OCRL	New in 2018	2	--	--
Thiazopyr	Water	Herbicide	4.1	4.1	ng/L	OCRL		2	--	--
Thiazopyr	Suspended Sediment	Herbicide	4.1	4.1	ng/L	OCRL		2	--	--
Thiobencarb	Water	Herbicide	1.9	1.9	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Thiobencarb	Suspended Sediment	Herbicide	1.9	1.9	ng/L	OCRL		2	1,000	Invertebrates - Chronic
Tolfenpyrad	Water	Insecticide	2.9	2.9	ng/L	OCRL		2	81.5	Fish - Acute
Triadimefon	Water	Fungicide	8.9	8.9	ng/L	OCRL		2	52,000	Invertebrates - Chronic
Triadimefon	Suspended Sediment	Fungicide	8.9	8.9	ng/L	OCRL		3	52,000	Invertebrates - Chronic
Triadimenol	Water	Fungicide	8.0	8.0	ng/L	OCRL		2	--	--
Triadimenol	Suspended Sediment	Fungicide	8.0	8.0	ng/L	OCRL		2	--	--
Triallate	Water	Herbicide	2.4	2.4	ng/L	OCRL		3	14,000	Invertebrates - Chronic
Triallate	Suspended Sediment	Herbicide	2.4	2.4	ng/L	OCRL		1	14,000	Invertebrates - Chronic
Tribufos	Water	Herbicide	3.1	3.1	ng/L	OCRL		1	1,560	Invertebrates - Chronic

Constituent	Matrix	Reporting group	RL	MDL	Unit	Lab	Note	Method	Min. OPP Aquatic Life Benchmark (ng/L)	Benchmark Category
Tribufos	Suspended Sediment	Herbicide	3.1	3.1	ng/L	OCRL		2	1,560	Invertebrates - Chronic
Tricyclazole	Water	Fungicide	4.1	4.1	ng/L	OCRL	New in 2018	2	--	--
Trifloxystrobin	Water	Fungicide	4.7	4.7	ng/L	OCRL		2	2,760	Invertebrates - Chronic
Trifloxystrobin	Suspended Sediment	Fungicide	4.7	4.7	ng/L	OCRL		2	2,760	Invertebrates - Chronic
Triflumizole	Water	Fungicide	6.1	6.1	ng/L	OCRL		2	33,000	Fish - Chronic
Triflumizole	Suspended Sediment	Fungicide	6.1	6.1	ng/L	OCRL		2	33,000	Fish - Chronic
Trifluralin	Water	Herbicide	2.1	2.1	ng/L	OCRL		2	1,900	Fish - Chronic
Trifluralin	Suspended Sediment	Herbicide	2.1	2.1	ng/L	OCRL		2	1,900	Fish - Chronic
Triticonazole	Water	Fungicide	6.9	6.9	ng/L	OCRL		2	--	--
Triticonazole	Suspended Sediment	Fungicide	6.9	6.9	ng/L	OCRL		2	--	--
Zoxamide	Water	Fungicide	3.5	3.5	ng/L	OCRL		2	3,480	Fish - Chronic
Zoxamide	Suspended Sediment	Fungicide	3.5	3.5	ng/L	OCRL		2	3,480	Fish - Chronic

Appendix 2 USGS PFRG Data Review Process

This information applies to all analytical results generated by the Pesticide Fate Research Group (PFRG) Organic Chemistry Research Laboratory (OCRL).

Following sample analysis at the OCRL all analytical results are reviewed by the USGS Project Director (PD) responsible for submitting the samples for analysis. Results are reviewed as they become available from the laboratory. The PD reviews each sample for completeness to ensure that all requested analytes have been quantitated, and reviews each analytical result for unexpected presence/absence or unexpectedly high or low result values (based on previous results and/or known trends in pesticide use and occurrence). If quality control samples were analyzed the PD reviews these samples to ensure that project measurement quality objectives, as outlined in the project Quality Assurance Project Plan (QAPP), have been met. During these review processes the PD flags any suspect results which are then sent back to the OCRL Chief Chemist (CC) for review. The CC then reviews the quantitation for any flagged results to verify the initial result or make corrections as appropriate. If questions persist as to the quality of the data, sample extracts may be reanalyzed. Additionally, samples with high results which fall outside the instrument calibration curve, may be diluted and reanalyzed at this time. The CC then returns the final, verified results to the PD for review. If questions regarding the data persist, the USGS California Water Science Center (CAWSC) Water Quality Specialist will be consulted to review the data and make any suggestions for corrective actions and/or proper coding of the data. If the PD has no further questions or comments about the data they are entered in the project specific data reporting spreadsheet.

At the end of the project, or at an earlier date as specified in the project QAPP or data management plan, the finalized data reporting spreadsheet is provided to the PFRG database manager (DM). The DM then enters the laboratory analytical results in the OCRL Access database which also contains field sample collection and laboratory sample tracking information. The DM then performs a semi-automated process to format the analytical results and necessary field collection information for entry into the USGS National Water Information System (NWIS) database. Once formatted, the data are uploaded to NWIS using a batch process. All data are uploaded to NWIS with a “Data Quality Indicator” code of “Provisional”. At this point the data are publicly viewable.

Prior to publication in any USGS series report the data undergo an additional, extensive review process. During this process the CAWSC Water Quality Specialist reviews the draft publication and data to ensure that they meet USGS accuracy and reporting standards. CAWSC data management staff (DMS) also review the data to verify that the data in the publication match the data stored in NWIS. Once the publication and data have been approved by the Water Quality Specialist and DMS the PFRG DM will switch the data quality indicator codes for all data results to “Reviewed and Accepted”.

In rare instances where OCRL data are not reported in a USGS series report or scientific journal the data will be reviewed and approved by the CAWSC Water Quality Specialist prior to the PFRG DM switching the data quality indicator codes to "Reviewed and Accepted".

The following information applies to results from the USGS National Water Quality Laboratory (NWQL), produced for projects managed by PFRG personnel.

Some research projects may require that samples be submitted to the NWQL for analysis. Analytical results produced by the NWQL are reviewed by the PD as they become available from the laboratory. The PD reviews each sample for completeness to ensure that all requested analytes have been reported, and reviews each analytical result for unexpected presence/absence or unexpectedly high or low result values (based on previous results and/or known trends in pesticide use and occurrence). If quality control samples were analyzed the PD reviews these samples to ensure that specific project measurement quality objectives as outlined in the project Quality Assurance Project Plan (QAPP) have been met. During these processes the PD flags any suspect results and may request a rerun of the sample if possible, or work with laboratory personnel to better understand/evaluate unexpected results. The PD also manually queries NWQL laboratory QC data for relevant analytical batches. These data are evaluated by the PD to determine if any environmental or field QC samples need to be coded in NWIS to reflect laboratory QC problems. All NWQL environmental, field QC, and laboratory QC data are entered in a project specific data reporting spreadsheet.

Environmental and field QC data produced by the NWQL are automatically flagged for some laboratory quality control issues as described in the NWQL's Quality Assurance and Quality Control Manual available at (http://wwwnwql.cr.usgs.gov/qas/QCM_v1.0.pdf). Data are automatically uploaded to the USGS NWIS database with a "Data Quality Indicator" code of "Provisional" At this point the data are publicly viewable.

Prior to publication in any USGS series report the data undergo an additional, extensive review process. During this process the CAWSC Water Quality Specialist reviews the draft publication and data to ensure that they meet USGS accuracy and reporting standards. CAWSC data management staff (DMS) also review the data to verify that the data in the publication match the data stored in NWIS. Once the publication and data have been approved by the Water Quality Specialist and DMS the PFRG DM will switch the data quality indicator codes for all data points to "Reviewed and Accepted".

In rare instances where PFRG project data produced by the NWQL are not reported in a USGS series report or scientific journal the data will be reviewed and approved by the CAWSC Water Quality Specialist prior to the PFRG DM switching the data quality indicator codes to "Reviewed and Accepted."

The following information applies to analytical results produced by the OCRL or USGS National Water Quality Laboratory (NWQL), which are submitted to non-USGS environmental databases (for example CEDEN).

Some research projects may require that analytical results be submitted to non-USGS environmental databases, in addition to NWIS, for storage. In addition to the data quality review procedures described earlier in this document, data destined for non-USGS databases undergo additional data formatting and review prior to submittal. After the data have been entered into the PFRG Access database the PFRG DM performs a semi-automated process to format the analytical results and necessary field collection information for entry into the external database using that database's coding and required fields. The formatted upload files are then provided to two USGS PFRG personnel for review. Each reviewer performs an independent review comparing analytical results, field collection information and method detection limits to data contained in the PFRG Access and USGS NWIS databases. Any discrepancies are flagged by the reviewers and the DM is notified. The DM makes any necessary corrections to the upload files which are then resubmitted to the reviewers to verify the corrections. Once this internal review process is completed the data are submitted to the non-USGS database and undergo any review processes pertinent to that database.

Appendix 3 Statistical Power Analysis

APPLIED MARINE SCIENCES

Technical Memorandum

TO: Matthew Heberger (Aquatic Science Center)

FROM: Aroon Melwani (Applied Marine Sciences, Inc.)

DATE: April 26, 2018

SUBJECT: Statistical Analysis to Support the Delta Regional Monitoring (DRMP) Program FY 2018 Pesticide Monitoring Designs

Background

The Delta Regional Monitoring Program (DRMP) includes evaluation of current-use pesticides and the extent to which they contribute to observed aquatic toxicity in the Delta. Between July 2015 and June 2017 (FY 2015-2016 and FY 2016-17), the DRMP collected baseline monthly water samples at five integrator sites that were analyzed for pesticides and paired toxicity analysis of 4-5 different species/endpoints (Figure 1). The DRMP is now undertaking an evaluation of these data to optimize the sampling design for future pesticides monitoring, with the specific goal of detecting a significant relationship between aquatic concentrations and toxicity.

On behalf of the DRMP Pesticides Subcommittee, the Aquatic Science Center contracted with Dr. Aroon Melwani (Applied Marine Sciences, Inc.) to conduct a power analysis and provide technical guidance towards employing a targeted or probabilistic sampling design for pesticides monitoring. The scope of work consisted of three tasks: 1) a preliminary analysis of variability in pesticide concentrations to inform stratification of baseline data, 2) evaluation of power to detect statistical relationships between pesticide concentrations and toxicity across a range of sample sizes, and 3) guidance on sampling effort and bias associated with probabilistic monitoring designs. This memorandum summarizes the results from these evaluations. This information is being used by the DRMP Pesticide Subcommittee to facilitate further discussions about an appropriate monitoring study design to address DRMP priorities.

Methods

A two-year dataset of 152 pesticides (including degradates) analyzed monthly between June 2015 – July 2017 at five integrator sites in the Delta were the basis for all statistical analyses discussed herein. Only dissolved pesticide concentrations were used.

Based on initial discussions with the Pesticides Subcommittee, these data were summarized for analysis using the Pesticide Toxicity Index (PTI) values, following the methods of Munn and Gilliom (2001) and Nowell et al. (2014). The PTI is an index that combines the measured concentrations of any number of pesticides into a single value, to assess the potential toxicity of pesticide mixtures to freshwater aquatic organisms. It is based on the concept of additive toxic units, well known in the field of risk assessment. TUs were calculated for individual compounds that were measured above the method detection limits, and summed for each location and sampling event using a database query in MS Access. The spreadsheet and database are available upon request from Matthew Heberger (matth@sfei.org).

Application of the PTI calculation to the pesticide concentration data resulted in a single index value for each analyzed sample (n = 24 per site; N = 120 total). It should be noted that several calculation assumptions exist for summarizing pesticide concentration into the PTI. To provide the most relevant and conservative calculation methodology for integration with the DRMP toxicity data, the Fish Sensitive and Cladoceran Sensitive calculations were used. Methods to represent an invertebrate endpoint or less conservative assumptions also exist.

Two chronic toxicity tests were selected for statistical evaluations based on recommendations from the Pesticides Subcommittee. For comparison to the Cladoceran Sensitive PTI, the *Ceriodaphnia dubia* reproductive test was selected (Figure 2), while for the Fish Sensitive PTI, the *Pimephales promelas* survival test was used (Figure 3). All toxicity results (as % effect) were included, irrespective if the result was statistically significant or not.

Task 1. PTI Variability

The PTI data were initially assessed for patterns in variability to generate appropriate simulated data for power analysis. Summary statistics of the PTI results for the five sites are provided for context (Tables 1 and 2).

An analysis of variance test was used to determine significant differences in the PTI data. Due to the lack of temporal resolution and replication (1 sample per site per month for two years; n = 2 per group), temporal effects could not be tested with this analysis. The analysis of variance thus focused on spatial variability.

Based on the ANOVA results, two variance groups were identified by pooling sites that were not statistically different ($p < 0.05$). Significance of groups was established through the use of 'dummy' variables for each site in the ANOVA tests. Subsequently, the mean, standard deviation, and coefficient of variation were calculated by stratifying the data into the respective groups ("A" and "B").

Task 2. Power Analysis

A power analysis simulation was designed to evaluate the necessary sample size to make statistical associations between PTI data and toxicity. The power analysis procedure simulated 2000 datasets, based on estimates of arithmetic mean and variability (standard deviation) in PTI for each variance group and sample size scenario. It assumed for each scenario that the modeled level of variation remains constant during the monitoring period. Sample size was varied from n = 12 to n = 240.

The statistical model for examining the PTI vs. toxicity relationship was:

$$y_i = y_o + r(PTI) + \varepsilon \qquad \textit{(Equation 1)}$$

Where, y_i = a simulated toxic effect value, y_o = the initial toxic effect value (intercept), r = slope of toxic effect vs. PTI (the effect size), PTI = individual pesticide toxicity index value, and ε (model error) is a normally distributed error term. The error term estimate was calculated as the standard deviation of the regression model error (i.e., sigma, δ). In employing this methodology, it is acknowledged that the model error estimate (ε) consists of the unexplained temporal variance as well as other potential driving factors.

Linear regression analysis was performed on each simulated dataset to determine statistical significance (p-value). The proportion of results that exhibited statistically significant slopes ($p < 0.05$) estimated the statistical power. The results of the power analysis were summarized in power curves (sample size vs. power) at varying effect sizes. The effect sizes selected were approximately an order of magnitude higher than the current size of the slope in the PTI: toxicity endpoint relationships.

Task 3. Probabilistic Monitoring

To address the final task in the scope of work, a technical review of the main concepts and recommendations for designing an ambient monitoring design was presented to the DRMP Pesticides Subcommittee. A summary of the design concepts discussed with the group is provided below.

Results

Task 1. PTI Variability

Two PTI datasets were assessed for spatial differences. Tables 1 and 2 summarize the mean PTI and variance for each site.[1] For either calculation model (Fish or Cladoceran), Ulatis Creek exhibited average PTI and standard deviation that was twice that of the other sites. As a result, two variance scenarios were developed (A and B) to represent the range in future pesticide distributions.

Task 2. Power Analysis

Summary statistics of the two groups (Table 3) indicate that the coefficient of variation in each group was similar, but Group B (only Ulatis Creek) exhibited higher pesticide concentrations (and thus higher PTI values) than Group A. No significant relationship was apparent in the baseline data for either scenario or toxicity endpoint (Figure 4).

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[1] In general, TU values approaching 1 are cause for concern. However, According to Nowell et al. (2004), PTIS is “not necessarily appropriate as a sensitive tool for predicting whether pesticide mixtures in water samples are likely to be toxic to aquatic organisms.” Rather, it was originally designed to be an indicator of relative toxicity. PTI values for samples, seasons, or sites have been used as explanatory variables in multivariate analyses designed to determine the environmental variables that best explain spatial patterns in the structure of a biological community.”

Power curves employing the Cladoceran PTI using the Group A scenario indicated that to detect an effect size = 0.03 with > 80% power would require ~ 60 samples (Figure 5). For an effect size = 0.02, the same variance scenario would require > 75 samples.

Due to higher concentrations under the Group B scenario, power indicated that smaller effect sizes could be detected with similar levels of effort to Group A (Figure 6). For example, where an effect size = 0.03 would require a minimum of 60 samples to achieve > 80% power in Group A, a similar level of effort could detect an effect size < 0.01.

In the scenarios to test the relationship between the Fish PTI and *Pimephales* toxicity, similar patterns were evident to the *Ceriodaphnia* results. Generally, the scenarios using Group B (Ulatis Creek) indicated 80% power could be achieved with similar levels of effort of Group A and 50% smaller effect sizes. This is important observation given the current lack of significant relationships at any of the sites. For example, an effect size of 0.3 with 60 samples would have > 80% power in Group B, as would an effect size of 0.6 with 60 samples in Group A.

Task 3. Probabilistic Designs

A probability sample is one where every element of the target population has a known likelihood of being selected. Two important features of a probability sample are that the site selection mechanism safeguards against selection bias, and is the basis for inference to characteristics of the entire target population. Good sampling designs tend to spread out the sample points more or less regularly.

U.S. EPA's Generalized Random Tessellation Stratified (GRTS) survey design methodology is a probabilistic sampling method for implementing a spatial survey (Stevens and Olsen, 2004), which has been adopted in many regional surveys in California and nationwide. GRTS incorporates several design concepts important for making inferences across a population with unbiased estimates of condition (Kincaid and Olsen, 2016), these include: 1) Stratified sampling; 2) Unequal probability sampling; 3) Panel sampling; 4) Over-sample selection.

No explicit guidance on the recommended sample size for GRTS survey designs exists. Budgetary and logistical constraints of individual study designs often dictate the level of effort employed. That said, probabilistic designs incorporating GRTS often aim to determine an estimate of a proportional extent, and thus refer to the binomial distribution to evaluate precision. Figure 7 depicts the binomial relationship between sample size and size of confidence interval for determining the likelihood that a sample estimate is within 80% of the population. In this scenario, a sample size of 30 would result in an estimated confidence interval of ~ 12%. Increasing the sample size would not significantly impact on the size of the confidence interval, while fewer than 30 samples would increase the confidence interval substantially. Consequently, a sample size of 30 can be considered an "industry standard", and has, in my experience, been selected as a default sample size in order to make statistical inferences about condition, with a relatively low degree of error. Ultimately, deciding upon an appropriate sample size for GRTS for the DRMP will require consideration of the monitoring objectives, precision desired, and the expected variability in the resource being sampled.

Conclusions

The take-home points from the power analysis simulations are:

- The Pesticide Toxicity Index does not exhibit a significant relationship with baseline DRMP toxicity results
- Ulatis Creek simulations indicate the highest probability of detecting small effect sizes in PTI-toxicity relationships in the future, due to the presence of some higher concentrations and toxic hits
- Using the Fish PTI, effect size would need to increase by 4-20x to detect significant relationship in the next 5-10 years (assuming n = 6-12/yr)

Overall, the baseline integrator site data set appears to only have captured a handful of high concentrations, which do not currently associate with toxicity results. The lack of extreme concentrations or frequently toxic samples in these short-term data sets does not necessarily mean that such events would not occur had a longer period been monitored. Though, it might just be as equally probable to spend continued effort to sample high concentrations / toxicity that are simply not present. Conversely, where high concentrations have been found (such as at Ulatis Creek), it is difficult to evaluate how common or rare such occurrences are, and what the underlying factors that are driving these variations. Therefore, the DRMP could benefit from implementing a probabilistic sampling approach, which incorporates spatial and temporal sampling to distinguish sites and seasons with sufficiently elevated concentrations to make associations with toxicity due to the presence of likely sources/runoff patterns. At a minimum, expanding upon the baseline resolution of pesticides sampling is a necessary next step for the Program.

References

Kincaid, T. M. and Olsen, A. R. (2016). spsurvey: Spatial Survey Design and Analysis. R package version 3.3.

Stevens, D.L., Jr., and Olsen, A.R. (2004). Spatially-balanced sampling of natural resources. Journal of the American Statistical Association 99: 262-278.

Figures

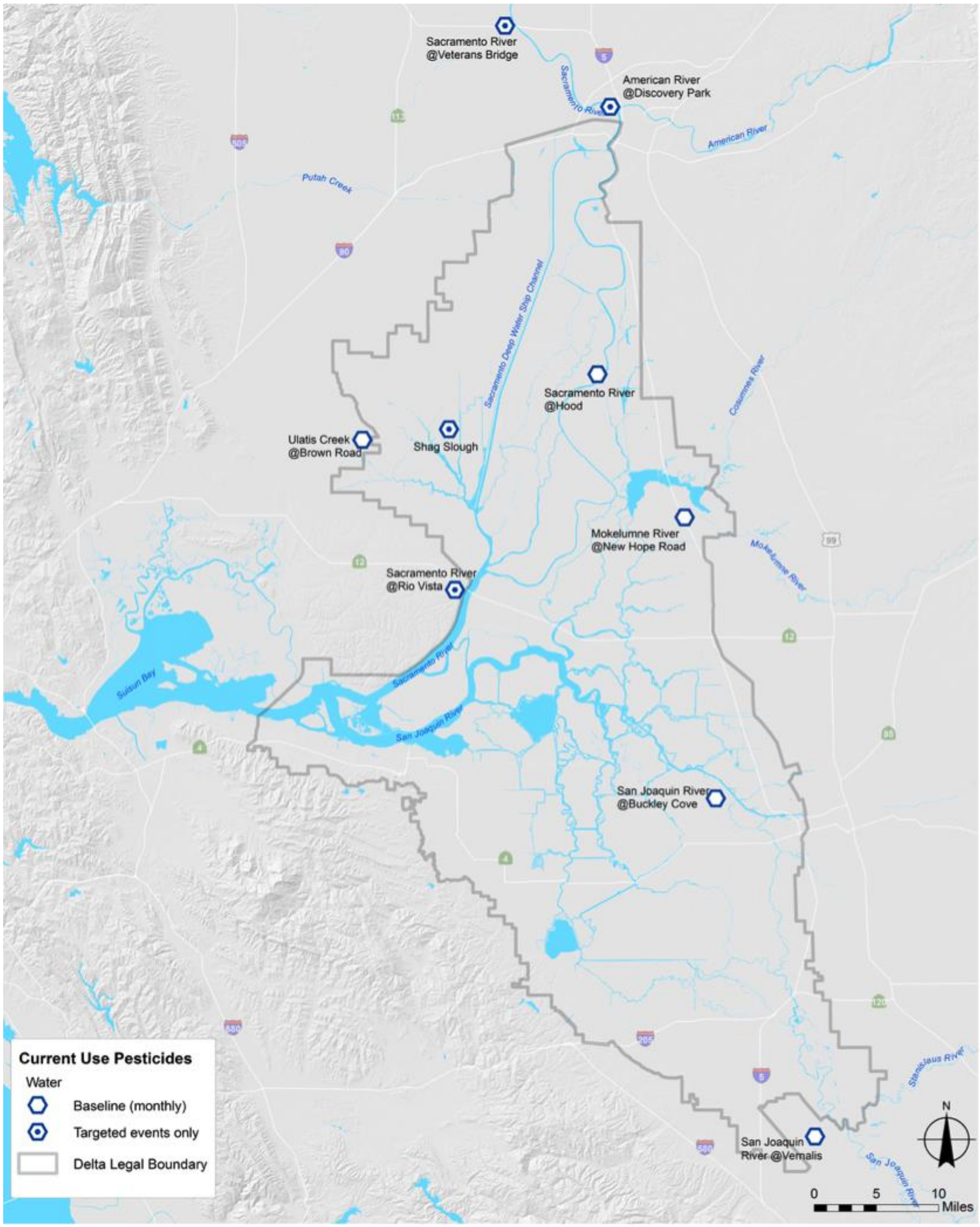

Figure 1. Map of Delta RMP integrator sites for pesticides sampling

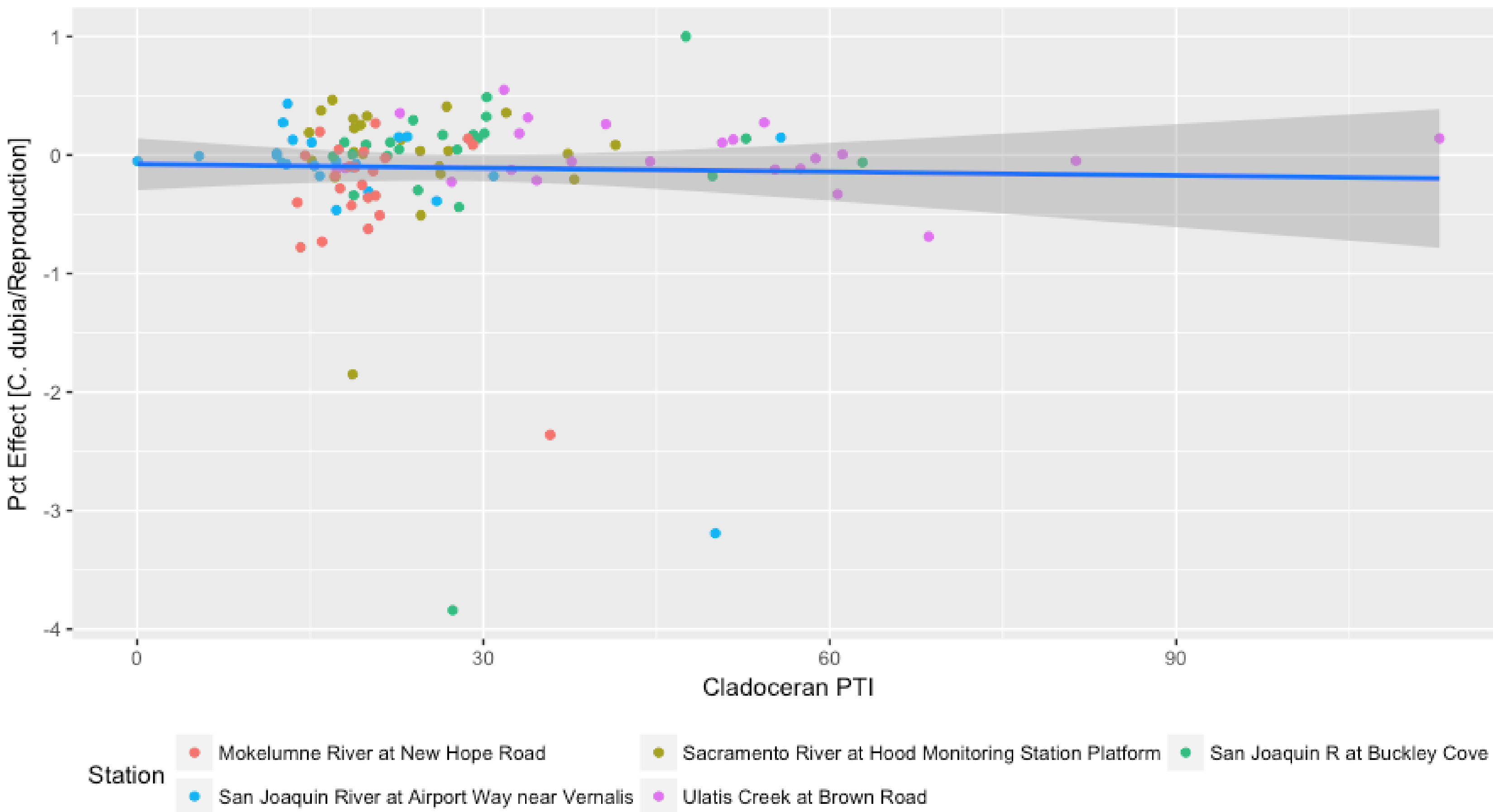

Figure 2. Pesticide Toxicity Index (PTI, Cladoceran) plotted against Percent Toxic Effect in *Ceriodaphnia dubia* / Reproduction test. Colors designate each site. The trend line indicates there is no clear relationship between the two variables.

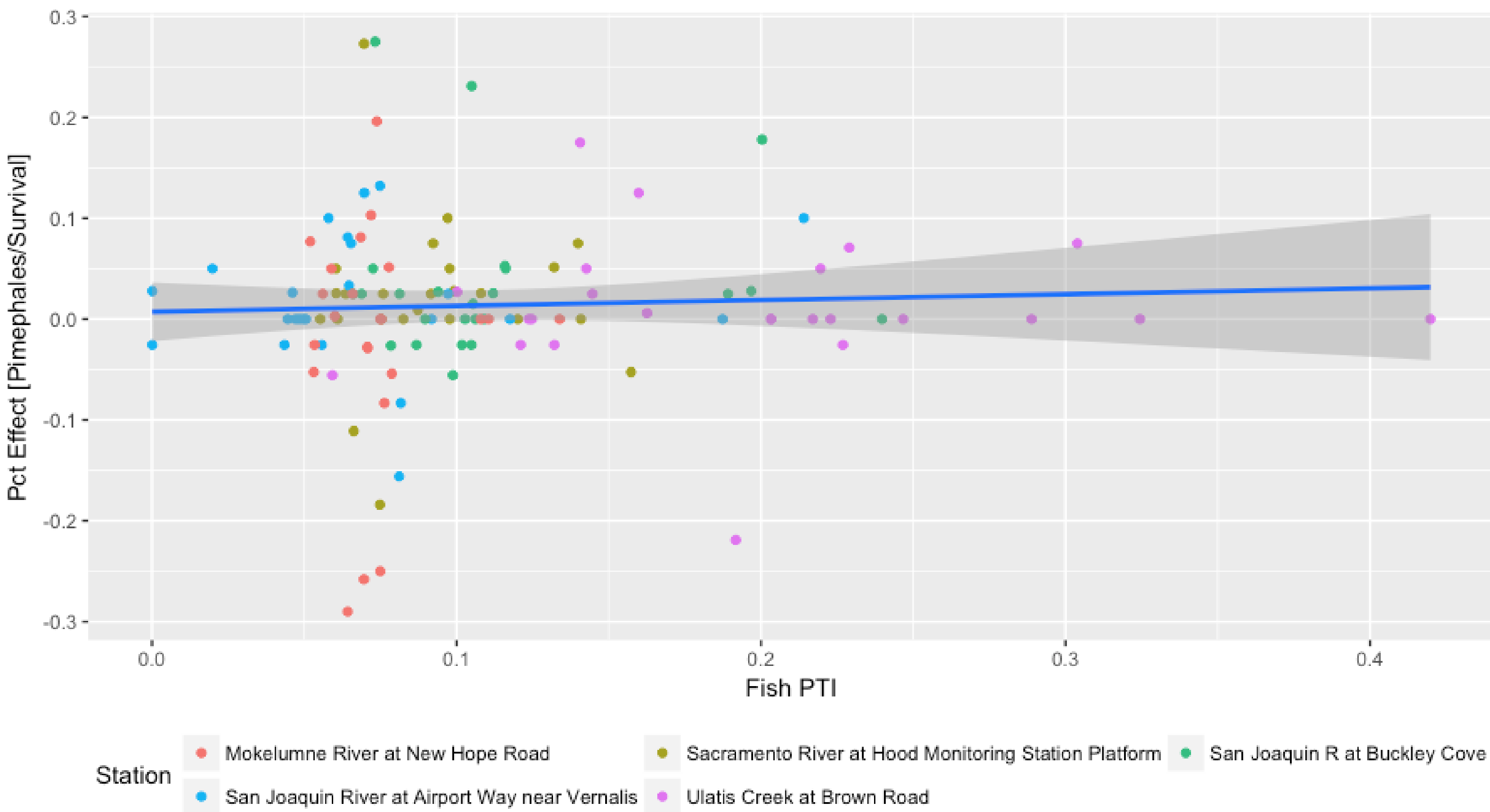

Figure 3. Pesticide Toxicity Index (PTI, Fish) plotted against Percent Toxic Effect in *Pimephales promelas* / Survival test. Colors designate each site. The trend line indicates there is no clear relationship between the two variables.

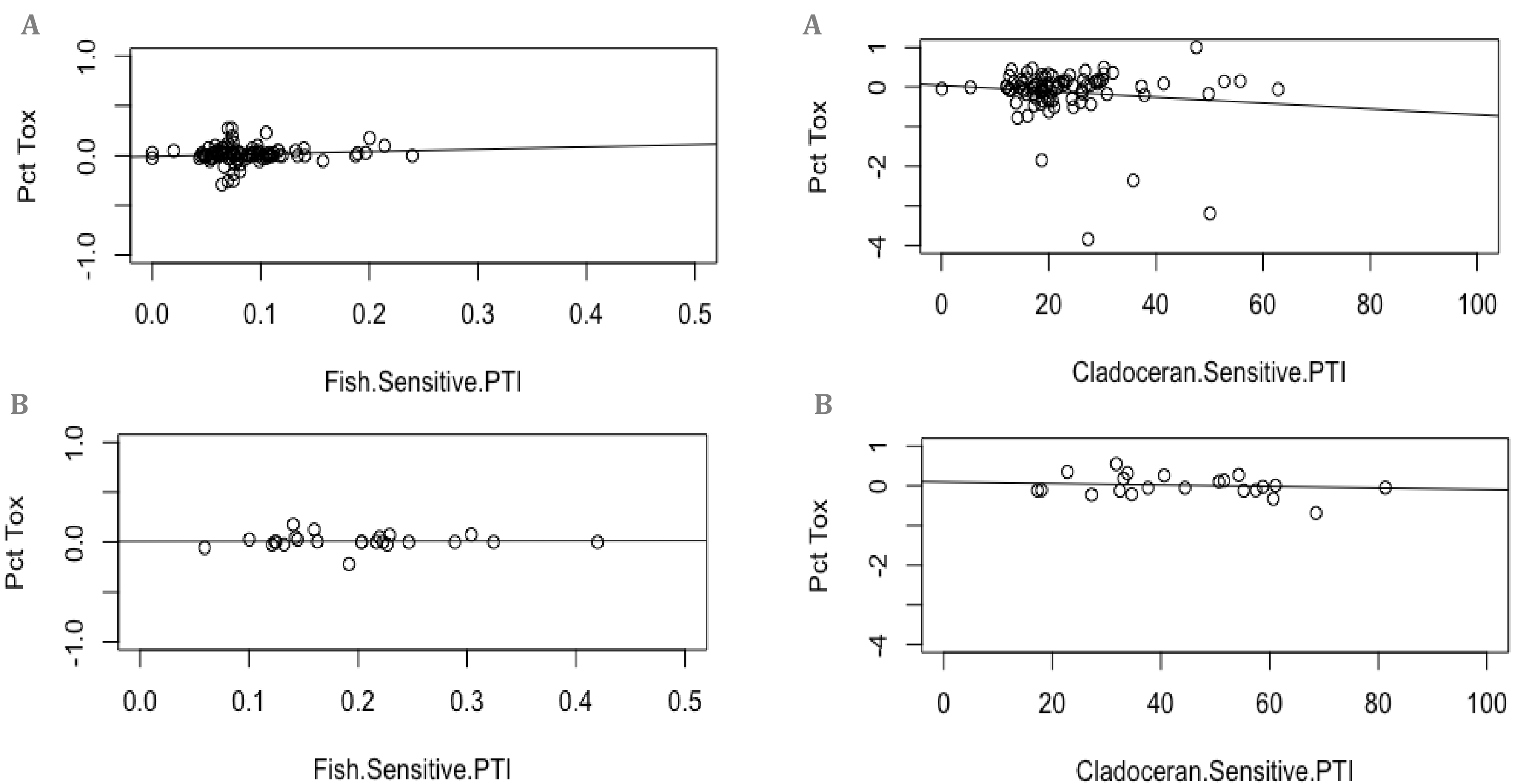

Figure 4. Pesticide Toxicity Index (PTI) plotted against Percent Toxic Effect for scenario A and B. Fish PTI data were plotted against *Pimephales promelas* / Survival test (left plots) and Cladoceran PTI were plotted against *Ceriodaphnia dubia* / Reproduction test (right plots). The trend line close to zero indicates there is no relationship between the two variables in any of the scenarios.

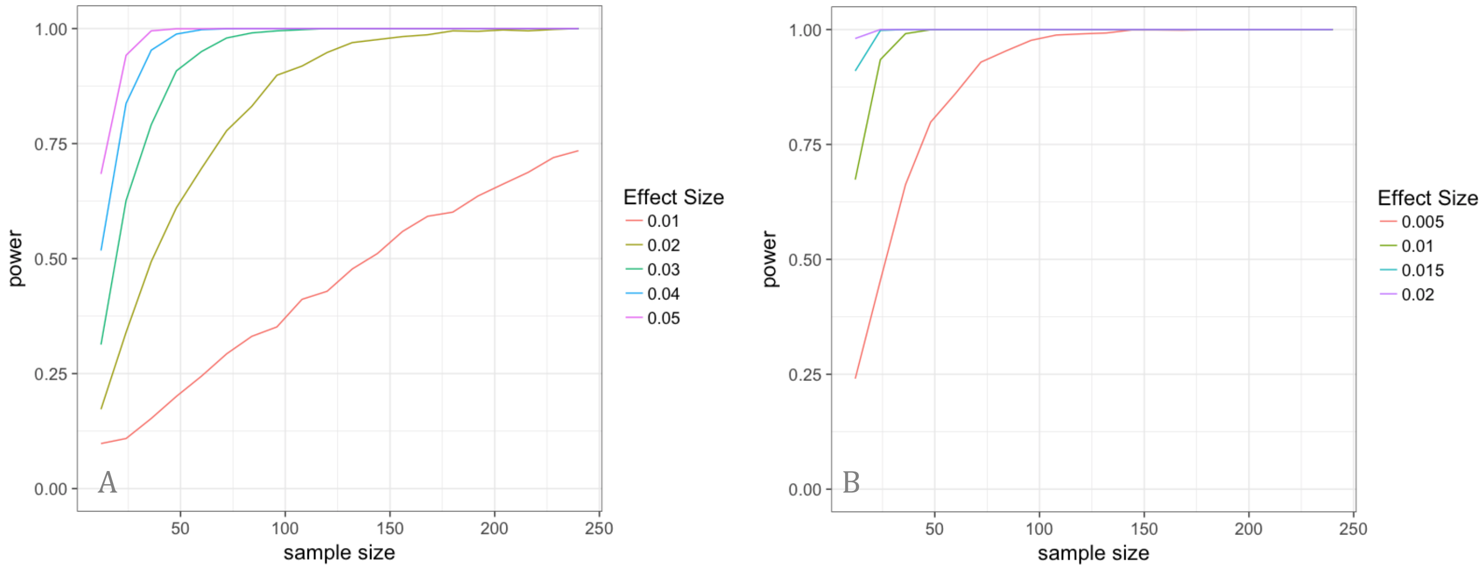

Figure 5. Power curve for scenarios A (left) and B (right) based on Cladoceran Sensitive PTI vs. *Ceriodaphnia* toxicity

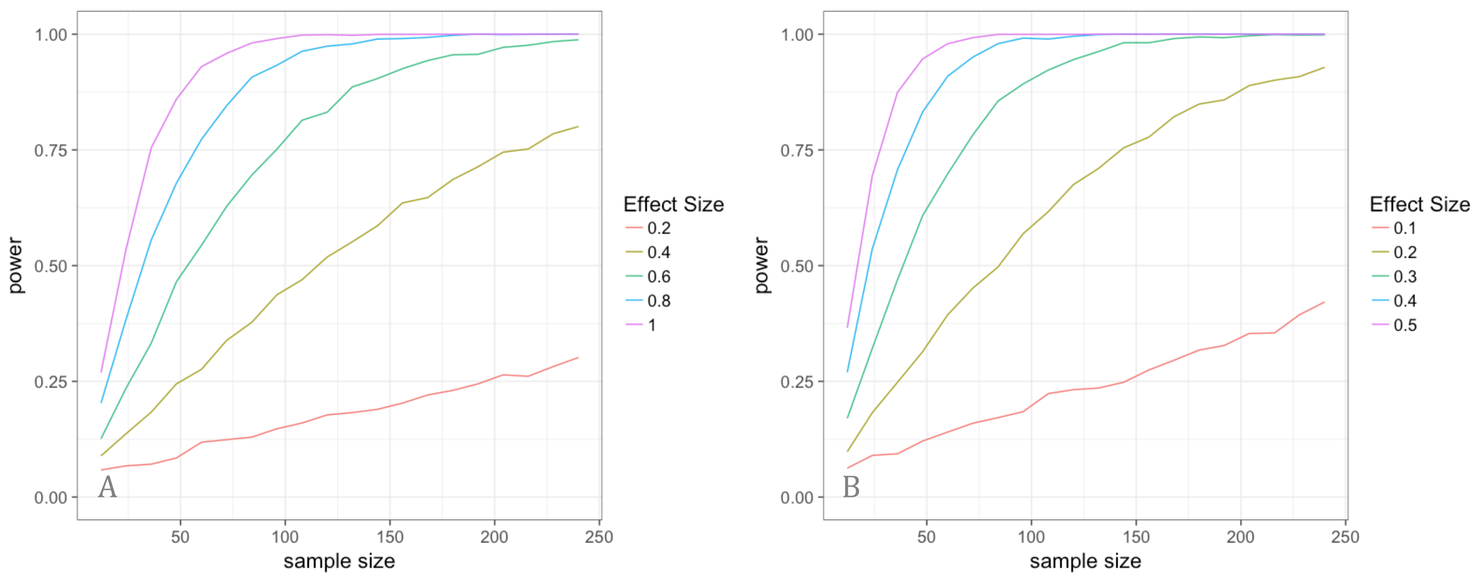

Figure 6. Power curve for scenarios A (left) and B (right) based on Fish Sensitive PTI vs. *Pimephales* toxicity

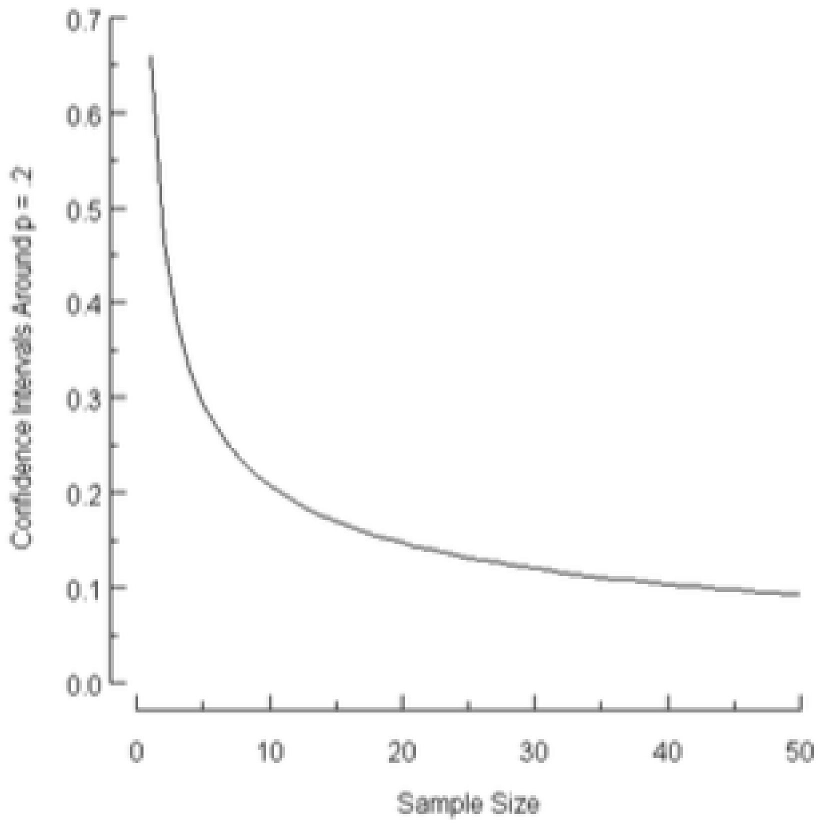

Figure 7. Sample size and size of confidence interval for a binomial distribution (p = 0.2)

Table 1. Mean, coefficient-of-variation, and result of ANOVA test on Pesticide Toxicity Index (Cladoceran-Sensitive)

PTI - Cladoceran Sensitive	Mean +/ SD	Coefficient of Variation	Statistical Difference
Mokelumne River at New Hope Road	20 +/- 5	26%	A
Sacramento River at Hood Monitoring	24 +/- 7	31%	A
San Joaquin R at Buckley Cove	29 +/- 12	40%	A
San Joaquin River at Airport Way near	18 +/- 13	69%	A
Ulatis Creek at Brown Road	47 +/- 22	46%	B

Table 2. Mean, coefficient-of-variation, and result of ANOVA test on Pesticide Toxicity Index (Fish-Sensitive)

PTI - Fish Sensitive	Mean +/ SD	Coefficient of Variation	Statistical Difference
Mokelumne River at New Hope Road	0.07 +/- 0.02	26%	A
Sacramento River at Hood Monitoring	0.09 +/- 0.03	31%	A
San Joaquin R at Buckley Cove	0.11 +/- 0.05	41%	A
San Joaquin River at Airport Way near	0.07 +/- 0.05	70%	A
Ulatis Creek at Brown Road	0.20 +/- 0.08	42%	B

Table 3. Variability estimates used for power analysis scenarios

Variance Group	**A**		**B**	
Station Composition	Hood, Buckley Cove, Mokelumne, Vernalis		Ulatis	
Predictor	Fish PTI	Cladoceran PTI	Fish PTI	Cladoceran PTI
N	96	96	24	24
Mean	0.09	23	0.20	47
SD	0.04	11	0.08	22
CV (%)	47%	46%	41%	46%

Appendix 4 Aquatic Toxicity Testing with *Chironomus dilutus*

Memo

To: Delta RMP Technical Advisory Committee and Steering Committee

From: Matthew Heberger, Aquatic Science Center

Date: June 19, 2018 (third revision)

Re: Information on aquatic toxicity testing with the midge larvae *Chironomus dilutus*

Delta RMP scientists have suggested adding the midge larvae *Chironomus dilutus* to our suite of test species for toxicity testing. This memo compiles some basic information about aquatic toxicity testing with this species. This memo includes information and text contributed by:

- Marie Stillway, Aquatic Health Program Laboratory at UC Davis
- Cameron Irvine, Robertson Bryan Inc.
- Stephanie Fong, State and Federal Contractors Water Agency
- Armand Ruby, Armand Ruby Consulting
- Danny McClure, Central Valley Regional Water Quality Control Board

Motivation for adding Chironomus

We are proposing adding *Chironomus* to our suite of test organisms in order to keep pace with changing use patterns of pesticides and aquatic toxicity in California. According to a 2015 memorandum from the Surface Water Ambient Monitoring Program (SWAMP):[1]

> As patterns of urban and agricultural pesticide use change in California, the species used to monitor water and sediment toxicity in SWAMP programs should be selected to properly evaluate these variations. While past data showed that much of the surface water toxicity was due to organophosphate pesticides such as diazinon and chlorpyrifos, these have largely been replaced by pyrethroids in most watersheds. In addition, recent data suggest new classes of pesticides are increasing in use, including phenylpyrazoles such as fipronil, and neonicotinoids such as imidacloprid. Decisions regarding toxicity monitoring for these pesticides should be based on their use patterns, and their relative toxicity to different test species and protocols.

Data show that *Chironomus* is more sensitive to fipronil and more sensitive in chronic exposures

[1] Brian Anderson et al., "Updated Recommendations for Monitoring Current-Use Pesticide Toxicity in Water and Sediment in the Surface Water Ambient Monitoring Program," SWAMP Technical Memorandum (Sacramento, California: State Water Resources Control Board, Surface Water Ambient Monitoring Program, 2015), https://www.waterboards.ca.gov/water_issues/programs/swamp/docs/workplans/tox_recs_tech_memo.pdf.

to neonicotinoids such as imidacloprid than the invertebrate *Ceriodaphnia dubia*, which has been the only invertebrate species tested by the Delta RMP in the past. According to UC Davis toxicologist Bryn Philips, "we are observing increasing sediment toxicity to *Chironomus* in urban SPoT samples over the last three years, whereas sediment toxicity to *Hyalella* has been decreasing at the same sites." This will be the subject of a forthcoming publication (in press).

Fipronil is recognized as a concern in the Delta, present in stormwater and wastewater effluent.[2]

Imidacloprid was one of our more frequently detected pesticides during the first 2 years of Delta RMP monitoring, often at levels above aquatic life benchmarks. As of 1999, imidacloprid was the most widely used pesticide in the world, and data from the California Department of Pesticide Regulation (DPR) confirms that it is widely used in an around the Delta and its watershed (Figure 1).

[2] Akash M. Sadaria et al., "Passage of Fiproles and Imidacloprid from Urban Pest Control Uses through Wastewater Treatment Plants in Northern California," *Environmental Toxicology and Chemistry*, 2016, http://onlinelibrary.wiley.com/doi/10.1002/etc.3673/full.

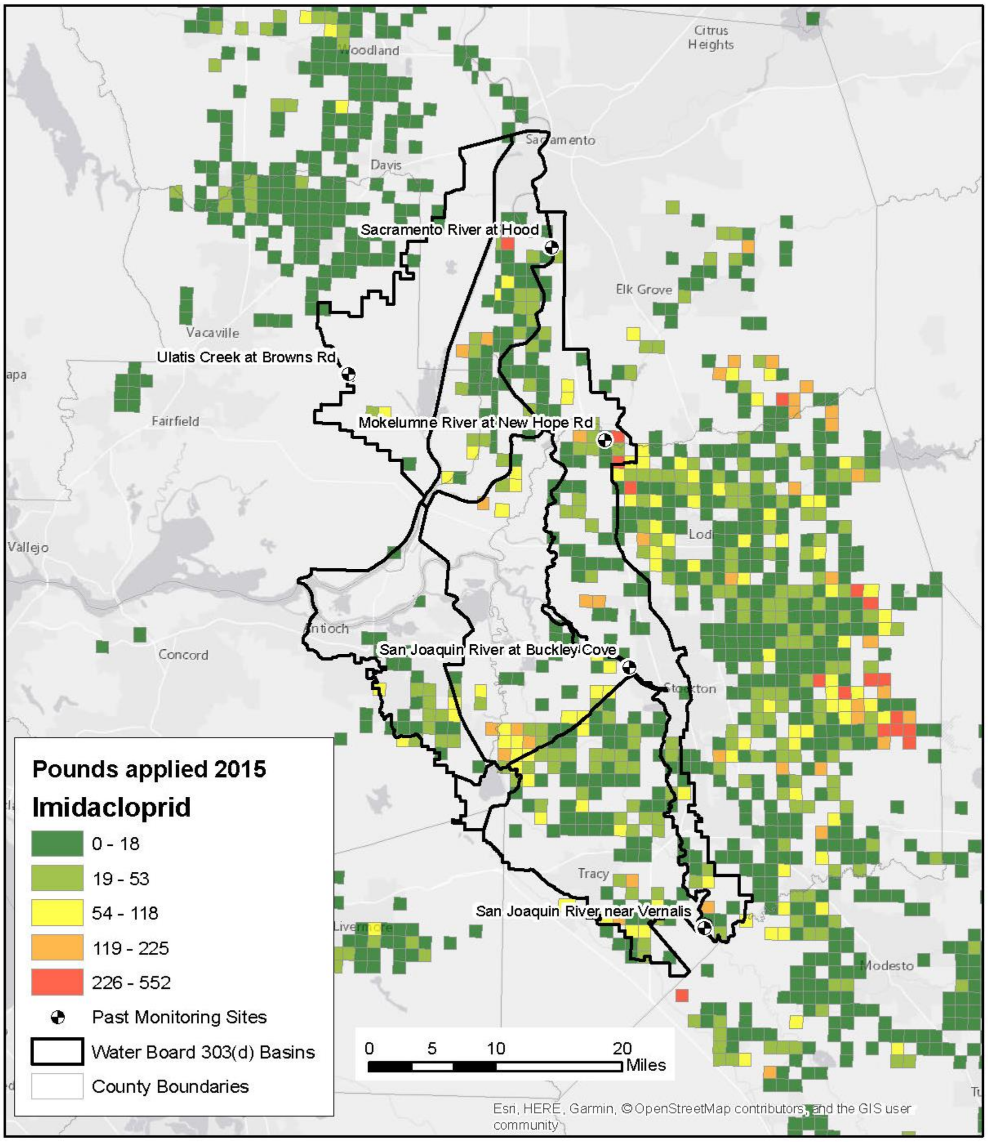

Figure 1 Application of imidacloprid near the Delta in 2015. Map by SFEI-ASC using data from DPR's pesticide use reporting database, http://www.cdpr.ca.gov/docs/pur/purmain.htm

About the species

Chironomus dilutus is the scientific name for a midge, a flying insect which has a global distribution.[3] The species was formerly known as *Chironomus tentans.* Midges are "informally known as chironomids, nonbiting midges, or lake flies" which superficially resemble mosquitoes.[4] Figures 2 and 3 show the larval and adult stages. In the last century, it was

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[3] SWAMP, "SWAMP Toxicity Test Species Highlight: Midge Larvae – Chironomus Dilutus," *SWAMP Newsletter*, no. 1 (2016), https://www.waterboards.ca.gov/water_issues/programs/swamp/newsletter/winter2016/test_species.pdf.

[4] "Chironomidae," *Wikipedia*, May 20, 2018, https://en.wikipedia.org/w/index.php?title=Chironomidae&oldid=842162410.

thought that adult midges did not feed, however, it has been found that many adults do feed. In general, the "larval stages of the Chironomidae form an important fraction of the macrozoobenthos of most freshwater ecosystems."[5] They are an important food source for a variety of fish and other aquatic organisms. Larval midges in the genus *Chironomus* typically inhabit the lower zone of water bodies. While they can tolerate low dissolved oxygen, they have also been described as an important indicator species, with their presence/absence a useful indicator of contaminant pollution.

Figure 2 Chironomus dilutus *(midge) larvae.*
Photo courtesy of U.S. Geological Survey

Figure 3 Adult midge, Chironomus dilutus.
Photo © 2011 [John F. Carr](#).

[5] "Chironomidae."

Use of Chironomus in aquatic toxicity testing

Chironomus has been referred to as a "commonly-used test species" and "widely used in standardized methods for testing with whole sediments measuring lethal as well as sublethal endpoints."[6] According to the USEPA, "many investigators have successfully used *C. tentans* to evaluate the toxicity of freshwater sediments."[7] The authors cite over a dozen examples from the literature spanning the years from 1977 to 1994. However, its use as a water-only test species is more recent and the test methods are not completely standardized.

Use at AHPL

The Aquatic Health Program Laboratory at UC Davis (AHPL) has been using *Chironomus* for water-only toxicity testing to analyze ambient water samples for the California Department of Pesticide Regulation (DPR). AHPL has recently been conducting water-only toxicity tests that evaluate organism survival over 96-hrs. This is an acute toxicity test; the lab has not yet run the chronic 10-day test. AHPL has used this method since 2017 and has run approximately eight samples and two reference toxicant tests to date, with seven more samples to be tested in June 2018.

The manager of the lab has offered to run some preliminary tests prior to the start of the project in order to gain extra experience with the 10-day test protocol.

A water-only protocol was developed by the UC Davis Granite Canyon Laboratory for survival and growth over 10-days, and is based on the EPA (2000) sediment toxicity test method. In place of an environmental sediment sample, clean sand is added to the bottom of the test chamber. The sand is important for the heath (i.e., reduced stress) of the organism, which likes to burrow and makes a case comprised of the substrate to live inside. Differences between the current UC Davis Granite Canyon lab test method and other potential test methods include the number of replicates, number of organisms per replicate, endpoints, feeding, and test acceptability criteria (**Table 1**). The Granite Canyon Lab supported updating their protocols to be consistent with pending updates to EPA (2000).

Use in Stormwater Sampling

It is becoming more common for *Chironomus* to be required as a test species in California municipal stormwater NPDES permits. As part of the statewide STORMS urban pesticides/ toxicity project, State Water Board staff worked with Regional Water Board staff in 2017 to compile statewide NPDES permit monitoring requirements for pesticides and toxicity testing (in water and sediment).

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[6] Guilherme Lotufo et al., "Assessing Biological Effects," 2014, 131–75, https://doi.org/10.1007/978-1-4614-6726-7_6.

[7] USEPA, *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates Second Edition*, EPA 600/R-99/064 (US Environmental Protection Agency, 2000), https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=30003SBA.TXT.

Per the results of that unpublished survey (2017), it turns out that only the SF Bay area (incorporating Region 2 and a small section of Region 5 in eastern Contra Costa County) requires municipal stormwater (MS4) agencies to include toxicity testing for *Chironomus* in water. The required sample numbers are small, and limited (annual) dry weather monitoring began last year; very limited wet weather monitoring occurred this past winter (all 10 samples required regionally during the five-year permit term were collected this wet season). Both the SF Bay area and Orange County (Region 8) require limited sediment toxicity testing using Chironomus.

The Bay Area toxicity testing is being done by Pacific EcoRisk, a commercial lab in Fairfield, California. The *Chironomus* method is a 96-hour survival test, using a water exposure test protocol based on modification of the US EPA guidelines.[8]

The fact that more California agencies do not require toxicity testing with *Chironomus* is not surprising, as the NPDES permit monitoring requirements are often dated, and permits are slow to address changes in pesticide use patterns. Many permits are still requiring monitoring for long-banned pesticides, and failing to include monitoring for the most problematic current-use pesticides. For instance, *Hyalella azteca* is an amphipod species sensitive to pyrethroid pesticides, yet *Hyalella* testing in water is only required for MS4s in Orange County and the SF Bay area. (*Hyalella* testing in sediment is more widely required, but still not universal.)

Two SF Bay area wet weather urban creek water samples from January 2018 both showed potentially toxic levels of bifenthrin, fipronil, and imidacloprid (estimated toxic unit equivalents >1.0 for each pesticide), and both samples were significantly toxic to *Hyalella*; however, neither sample was toxic to *Chironomus* (Armand Ruby, personal communication).

Test Methods

The specific test method to be used in testing will need to be identified. There is not yet a standard SWAMP (2008) method or measurement quality objectives (MQOs) for testing midge, and EPA guidance only includes a water-only method evaluating survival over 96-hrs (reference tox for the sediment test). However, the EPA and ASTM methods are being updated and are expected to include water-only test methods (Table 1). Drafts of these updates are currently available.

EPA (2000) sediment toxicity testing guidance describes a 96-hr water-only reference toxicity test with midge evaluating survival. Sediment tox testing methods for *Chironomus dilutus* evaluate survival and growth over 10-days, and a 60-65-day life-cycle test

SWAMP (2008) MQOs describe several sediment toxicity testing methods but none for the midge. Data developed without SWAMP MQOs cannot be validated and are flagged as

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[8] USEPA.

“screening” when reported in the California Environmental Data Exchange Network (CEDEN).

EPA (2000), and the corresponding ASTM method, are being updated and will more explicitly include water-only test guidance (described below). Drafts of both documents were distributed for limited external review in August-2017 and are currently being revised. Reviewers were given the following charge:

> “For the 1st and 2nd editions of the USEPA freshwater sediment test methods, considerable effort was directed to keeping the USEPA methods and the parallel methods described by ASTM (E1706 and E1688) consistent with one another. Toward that end, Chris Ingersoll of ASTM Sub-Committee E50.47 on Biological Effects and Environmental Fate (formerly Committee E47) has organized a simultaneous review of revisions to the ASTM versions of the *Hyalella azteca, Chironomus dilutus,* and *Lumbriculus variegatus* test methods that match those in the draft USEPA revision. Response to reviews of the USEPA method and the ASTM methods are being coordinated, so if you are contacted about both reviews, you may respond to either one and your comments will be considered under both.”

According to the ASTM document lead author, an updated draft – at least for the ASTM method – is expected this fall. Delta RMP TAC member Cameron Irvine is the chair of the ASTM subcommittee responsible for this review and balloting and has promised to keep us posted on its status. The EPA version is being updated in parallel.

Test Repeatability / Lab intercalibration

One way to check the validity and repeatability of a method is to perform a laboratory intercalibration. When a single sample is split and sent to multiple labs, it is sometimes referred to as a “round robin.”

At the present time, the water-only method with *Chironomus* is not performed widely. Nonetheless, a round-robin-style laboratory intercalibration would be very informative in describing the reliability and reproducibility of test methods among labs. While the water-only method would be new to most labs, it is common for EPA-led round robin testing to include labs that are both experienced and inexperienced with proposed test methods.

Interlaboratory comparison testing is an appropriate and important step to take when developing and using new methods, even if only among a few labs, but it was not considered by the TAC toxicity workgroup (5/24/18 meeting) to be a requirement for the draft 2018 Delta RMP Pesticide monitoring plan and no funding seems to be currently available. In the future, when funding is identified, it would be appropriate to participate in or help organize a round-robin-style laboratory intercalibration study with *Chironomus* in water-only toxicity testing.

SWAMP has suggested that it could include a *Chironomus* water-only laboratory intercalibration study in their budget planning in 2019. It has also been suggested that the Delta RMP could seek funding for a *Chironomus* toxicity intercalibration study via Supplemental Environmental

Project (SEP) funding, an alternative to penalties paid by dischargers for permit violations. However, an intercalibration study is probably not a good candidate for SEP funding. Projects are supposed to be connected to the area in which the fine is associated. While lab studies help inform all future studies, the link is not strong, and thus this may not be attractive to potential funders.

Conclusions

- *Chironomus* sp. have been widely used for four decades to test 96-hr water-only (survival) and sediment toxicity.
- The TAC toxicity workgroup recommends using a 10-day test method to evaluate survival and growth (weight and biomass) over the 96-hour test method (survival) to take advantage of midge sensitivity to some current use pesticides.
- A specific test protocol will need to be identified.
- Standardized midge test methods are currently being updated by SWAMP, ASTM, and the USEPA that will include water-only testing, and both 10-d and 96-h test durations.
- The Delta RMP is not a regulatory program, but data produced by the Delta RMP are intended for use by regulators and for regulatory decisions. Therefore, it would be appropriate for the program to develop high-quality data based on reproducible and reliable methods that are technically defensible.
- We should strive to make our testing methods be consistent with the draft update to EPA methods that are expected to be finalized in the near future.

Table 1. Current *Chironomus riparius* toxicity test method summary in water-only exposures.

Parameter	EPA (2000) (96-hour ref tox) single organism per chamber	EPA (2000) (96-hour ref tox) multiple organism per chamber	EPA / ASTM (10-day) (update in progress)	Granite Canyon Lab (10-day)	U.C. Davis AHPL (96-hour toxicity test and ref tox)
Test Duration (days)	4		10	10	4
Test vessel	30-mL plastic cups	250-mL glass	300 mL glass	300 mL glass	300-mL glass
Volume of test solution (mL)	20	100	175 mL	200	200
Number of organisms per replicate	1	10	10	12	12
Number of replicates per treatment	10	3	8 (min 4)	4	4
Feeding	0.25 mL Tetrafin® (4 g/L stock) on Day 0 and 2	1.25 mL Tetrafin® (4 g/L stock) on Day 0 and 2	Feed a suspension of fine fish-food flakes (not blended) at a rate of 6 mg for test day -1, 2 mg/day for test days 0 to 3, 4 mg/d for days 4 to 6, and 6 mg/d for days 7 to 9.	0.5 mL of 4 g/L Tetramin® slurry for the first 4 days, 1.0 mL the middle 3 days, and 1.5 mL the final 3 days of the test.	0.5 mL of 4 g/L Tetramin® slurry at test initiation, and at 48-hr water renewal
Water Renewals	none		2 volume additions/d (e.g., one volume addition every 12 h).	50% every other day	60% at 48-hrs
Control/dilution water	Culture water, well water, surface water, site water, or reconstituted water			Granite Canyon well water	Reconstituted water
Organism age (days)	second- to third-instar larvae (about 10-d-old larvae)[1]		From a single culture cohort, 7-10 day old & within 24 h age, and ≤ 0.12 mg/individual at the start of test.	7-day post hatch with all organisms from the same culture (2-3 instar)	
Substrate	sand (monolayer)		5 – 10 mL neutral substrate such as clean quartz sand	Clean sand (5 mL)	
Number of ref tox concentrations	Control + 5 test concentrations		-	-	NA for tox test / Control + 5 test concentrations for RT
Temperature	23 ± 1 ° C		23 ± 1 ° C	23 ± 1 ° C	23 ± 1 ° C
Lighting	About 100 to 1000 lux			10 – 20 µE/m2/s or 50 – 100 ft-c	
Photoperiod	16L:8D			16L:8D	
Oxygen/aeration	None		If DO < 2.5 mg/L	If DO < 2.5 mg/L	
Endpoints[7]	Survival (LC50)		Survival, growth (AFDW), biomass	Survival and growth (AFDW)	Survival
Test acceptability criteria (Controls)	≥ 90% control survival		≥ 90% control survival; AFDW ≥ 0.60 mg/individual.	≥ 70% control survival; AFDW ≥ 0.48 mg/ individual	≥ 90% control survival

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Water Quality	Hardness, alkalinity, conductivity, DO, and pH at the beginning and end of a test. Temperature daily		Temperature daily and hardness, alkalinity, conductivity, pH, and ammonia in each treatment at the beginning and end of a test. DO three times per week in each treatment (more often if DO < 2.5 mg/L)	DO, pH, conductivity, and ammonia are measured at the beginning and end of the exposure. Temperature is measured continuously, and hardness and alkalinity are measured at the beginning of the test.	DO, pH, conductivity and temperature are measured at the beginning and end of the exposure. Temperature is monitored continuously. DO and pH are measured in new renewal water and in 48-hr old water. Hardness alkalinity and ammonia are measured at the beginning of the test.

Notes:

Highlights indicate relevant information differs among tests.

AFDW – ash free dry weight

DO – dissolved oxygen

LC50 – lethal concentrations for 50 percent of test organisms

[1] Age requirement: All animals must be third or second instar with at least 50% of the organisms at third instar.

Attachment D CECs Planning and Monitoring Design

Contaminants of Emerging Concern Planning and Monitoring Design Workplan for FY18/19

Estimated Cost

The Stakeholders agreed to initiate the project in FY18/19 through development of the Quality Assurance Project Plan (QAPP) and planning and procurement efforts in coordination with the TAC CEC Subcommittee. Sample collection is planned to begin in FY19/20, or after July 1, 2019.

FY18/19

Planned expenses for FY18/19 are $45,000, primarily for labor by the Aquatic Science Center (ASC). ASC prepared a detailed cost estimate for 1) QAPP development and 2) an additional contingency amount was estimated to support the initial set-up of the program:

A. $23,000 for QAPP revisions and approval through SWAMP – cost estimate provided by ASC, see budget table below. In September 2018, the Delta RMP TAC advised that the QAPP for CEC monitoring should be a standalone document rather than an amendment to the existing Delta RMP QAPP.

B. $22,000 Program implementation - optimization of Pilot Study Work Plan, logistics planning, sample collection and analysis vender selection process administration, contract set-up with venders, coordination with other monitoring programs, facilitation of TAC CEC Subcommittee, and start-up mobilization for FY19/20 sample collection. This initial cost estimate to be refined and confirmed by ASC prior to the July 17, 2018 Steering Committee meeting.

FY19/20, FY20/21, and FY21/22

Sample collection begins in FY19/20 and the three sample collection years are budgeted at approximately $200,000 annually. These costs will be further refined during FY18/19 planning.

Oversight Group

Technical Advisory Committee (TAC) Contaminants of Emerging Concern (CEC) Subcommittee

Work Plan Development

Stakeholder group of MS4s, POTWs, State Water Resources Control Board (State Board), and Central Valley Regional Water Quality Control Board (Regional Board), collectively referred to as "Stakeholders".

Work Plan Overview

The Pilot Study Work Plan includes water column, sediment, and tissue sample collection at Delta and immediate tributary locations over a three-year sample collection period. Following a planning and mobilization year (FY18/19), the first two years of sample collection include ambient surface waters, tissue, and sediment sample collection. The second and third years include "source" water sample collection—wastewater treatment plant effluent and stormwater runoff. Finally, the Pilot Study Work Plan includes a gradient study in the third year.

The three-year Pilot Study Work Plan has been approved by the Regional Water Board and State Board staff.

The Stakeholders presented the Pilot Study Work Plan approach to the Delta Regional Monitoring Program (Delta RMP) Steering Committee on multiple occasions dating back to the October 24, 2017 Joint TAC-Steering Committee meeting. At that time specific funding guidance was provide to the TAC for other study components (methylmercury, nutrients, and pesticides) and CEC work was acknowledged as a special study for consideration with available funds. The TAC has provided comments only on specific questions from the Steering Committee (March 2, 2018 meeting), and this workplan was developed by the TAC CEC Subcommittee.

Schedule and Deliverables

Subtask	Deliverable	Due Date
A	Draft Delta RMP CEC Monitoring QAPP	Feb 2019
	Final Delta RMP CEC Monitoring QAPP	June 2019
B	Draft Detailed Sampling and Analysis Plan	Feb 2019
	Final Detailed Sampling and Analysis Plan	May 2019

Table: Budget for amending the Delta RMP Quality Assurance Program Plan (QAPP) to cover CEC monitoring

Hours by Subtask	Program Manager	Environmental Scientist	Data Mgmt Staff	QA Officer	Total Hours	Amount
Compile Method Details from Laboratories	4	16	-	-	20	$1,796
Prepare CEC Section in QAPP	8	40	24	24	96	$11,355
Get Lab QAOs Approvals	4	4	-	-	8	$813
Get SWAMP QAO Approval	16	16	8	8	48	$5,622
Get TAC Approval	4	4	8	8	24	$3,183
Get final signatures	4	-	-	-	4	$486
Total Hours	40	80	40	40	200	$23,255