Table 1: Summary of Proposals for RMP Special Studies in 2024

Workgroup	Study Name	PI / Agency	Funding Request	Ranking	Time sensitive	Multi-year study	Multi-workgroup study	Notes	Page Numbers
Emerging Contaminants	Stormwater CECs Monitoring and Modeling 2024	Moran / SFEI	$300,000	1	Y	N	Y	$100,000 (WQIF), Early release of RMP funds requested	6-12
Emerging Contaminants	Tire and Rodaway Contaminants in Wet Season Bay Water Year 3	Miller / SFEI	$50,000	2	Y	Y	N		13-21
Emerging Contaminants	OPEs, Bisphenols, and Other Plastic Additives in Wastewater	Mendez / SFEI	$95,400	3	N	N	N	Strong support for including the expanded list of plastic additives	22-32
Emerging Contaminants	PFAS Synthesis & Strategy	Lin / SFEI	$107,000	4	Y	N	N		33-39
Emerging Contaminants	PFAS in Bay Water using the TOP Assay	Mendez / SFEI	$67,200	5	Y	Y	N	Leveraging S&T water monitoring in 2023 & 2024; sediment monitoring was not considered a priority, so this was excluded from the recommended scope and budget	40-49
Emerging Contaminants	Non-targeted Analysis of SF Bay Fish Year 1	Miller / SFEI	$23,000 (Year 1 only)	6	Y	Y	N	$85,000 for both years; Sample collection ($25,000) not included as it will be covered by S&T	50-58
Emerging Contaminants	PFAS and Nontrageted Analysis of Marine Mammal Tissues Year 2	Miller / SFEI	$126,500	N/A	Y	Y	N	S&T Pilot study	59-70
	Total		**$619,600**						
Microplastic	Microplastics Stormwater Monitoring Pilot	Lin / SFEI	$119,500	1	Y	Y	Y	$119,500 (Yr. 1: $68,100)	71-78
Microplastic	Size Distribution of Microplastic Particles in SF Bay	Miller / SFEI	$65,000 - $105,000	N/A	N	N	N	SEP Proposal; $65,000 for water only, $105,000 for water and sediment.	79-91
	Total		**$119,500**						
Nutrients	Moored sensor high-frequency observation network	Senn / SFEI	$250,000	N/A	Y	Y	N	Additional $190,000 in matching funds from NMS	
	Total		**$250,000**						
Sediment	Spatial variability of sediment accretion in San Francisco Bay restorations	Thorne / USGS	$203,528	1	N	Y	N	Fund over two years, $130k yr 1; $75k yr 2? Roughly a per site cost, so could adjust as needed. Data release in Sep 2025 so others can use the data earlier than project completion.	92-102
Sediment	Continuous Suspended Sediment Concentration and Wave Monitoring in South and Lower South San Francisco Bay - Year 3	Mourier / SFEI	$83,558	2	Y	Y	N	rescoped to include - synthesis from tier 3, but not tier 2 sampling	103-113
Sediment	Sediment load from Bay area watersheds under future climate	Zi / SFEI	$82,325	3	N	N	Y	Possibly adapt scope based on priorities for SPLWG and model updates. Add project to the SEP list at a minimum. Possible proposal for 2025 funding.	114-120
Sediment	Sediment Conceptual Model(s) for Individual San Francisco Bay Segments and Subembayments		modular	N/A	N	N	N	SEP proposal	NA
	Total		**$369,411**						
Sources Pathways and Loading	Integrated Monitoring and Modeling to Support PCBs and Mercury Watershed Loads Uncertainties Assessment and Monitoring Design	Avellaneda / SFEI	$217,000	1	N	Y	Y	$217K in 2024, $167K in 2025	120-129
Sources Pathways and Loading	Tidal Area Remote Sampler Pilot - Year 2	Gilbreath / SFEI	$62,000	2	N	N	Y	Year 2 of 2-year project. Full budget for 2024 is $107K ($45 can be carried over from 2023). Could be reduced from $62K if needed, 8 sites (for 5 sites the cost would be $47K)	130-135
Sources Pathways and Loading	Pilot Study Using a Detection Dog Team for Source Tracing of PCBs in Old Industrial Areas of the San Leandro Bay Watershed	Gilbreath / SFEI	$25,000	3	Y	N	Y	Smaller budget recommended to scope this out in more detail.	136-145
Sources Pathways and Loading	Remote Sampler Purchase	Moran / SFEI	$180,000	N/A	Y	N	Y	General RMP Proposal	146-152

Table 1: Summary of Proposals for RMP Special Studies in 2024

Workgroup	Study Name	PI / Agency	Funding Request	Ranking	Time sensitive	Multi-year study	Multi-workgroup study	Notes	Page Numbers
Sources Pathways and Loading	Watershed Dynamic Model Maintenance	Zi / SFEI	$50,000 annually	N/A	Y	Y	N	General RMP Proposal. Will be vetted to ensure no double-dipping with Proposal #1	153-158
	Total		**$304,000**						
PCBs	Priority Margin Unit Shiner Surfperch PCB Trend Monitoring	Davis / SFEI	$20,000	1	Y	N	N	Would make sense to move to S&T.	159-168
PCBs	Monitoring of Sediment Deposition in San Leandro Bay Intertidal Areas	Yee / SFEI	$76,000	1	Y	N	Y	Options available for a larger scope.	169-175
	Total		**$96,000**						

Table 2: Short Descriptions of Proposals for RMP Special Studies in 2024

Workgroup	Study Name	Budget	Summary	Deliverables
Emerging Contaminants	Stormwater Contaminants of Emerging Concern (CECs) Monitoring and Modeling 2024	$300,000 (RMP) $100,000 (WQIF)	This project will begin implementing the RMP stormwater CECs integrated modeling and monitoring program. This proposal is a placeholder for completing and implementing the integrated modeling and monitoring program in wet season 2023/2024 (October 2023-September 2024) that will be defined by the Stormwater CECs Approach. It includes scopes and budgets for four specific tasks for which we request early release of funds to initiate implementation in summer 2023. It briefly outlines remaining tasks, which will be developed in concert with the completion of the Approach. These tasks will be developed under the oversight of the SST in parallel with the Approach and brought to the TRC and SC for approval.	Task 1: scopes and budgets presented for SST review and SC approval. Task 2: summaries from SST meetings, the two RMP presentations, and the conference presentation. Task 3 will be integrated into the Stormwater CECs Approach draft report to be completed in fall 2023 and final report to be completed by spring 2024.
Emerging Contaminants	Tire and Roadway Contaminants in Wet Season Bay Water Year 3	$50,000	6PPD-quinone and other toxicologically relevant contaminants derived from tires have been observed in Bay Area stormwater and in wet season Bay water samples from 2021 and 2022. As part of its Status and Trends (S&T) program, the RMP is undertaking a pilot monitoring effort to quantify a number of contaminants in Bay water samples collected following storm events to provide information on the impact of stormwater discharges on Bay contaminant concentrations. This proposed study, the third and final year in a multi-year monitoring effort, would leverage the pilot S&T effort to evaluate more fully the concentrations of tire and roadway contaminants in Bay water during the wet season. Results will indicate whether these stormwater-derived contaminants reach concentrations of concern within receiving waters, filling a data gap relevant to the RMP's tiered risk-based framework for emerging contaminants. Results will be shared with the California Department of Toxic Substances Control's Safer Consumer Products Program, which seeks data to support its evaluation of tire chemical ingredients.	Update sampling plan, field sampling, lab analysis, QA/QC, data management, data upload, presentation at ECWG 2025, draft and final report
Emerging Contaminants	OPEs, Bisphenols, and Other Plastic Additives in Wastewater	$95,400	Plastic additives are an extensive group of chemicals used in the production of plastics for a variety of consumer, commercial, and industrial applications. Many of the chemical classes that comprise plastic additives, especially organophosphate esters (OPEs) and bisphenols, are ubiquitous in the environment. In addition, many of these compounds are known to be toxic and exhibit a variety of effects on humans and animals. The RMP has previously found OPEs and bisphenols in wastewater, stormwater, and ambient Bay water. The RMP currently classifies both as a Moderate Concern within the RMP tiered risk-based framework for emerging contaminants. To build on these previous efforts, we propose a study to assess the concentrations of OPEs, bisphenols, and other plastic additives in Bay Area wastewater effluent. Analysis of OPEs is a particularly high priority to allow for an assessment of the relative importance of stormwater versus wastewater pathways to the Bay. Leveraging a study of OPEs to include other plastic additives is a cost-effective way to gain more information on a broader list of widely used and potentially toxic compounds.	Develop sampling plan, field sampling, lab analysis, QA/QC, data management, draft report, final report, presentation at ECWG 2026
Emerging Contaminants	PFAS Synthesis & Strategy	$107,000	This proposed synthesis and strategy revision would provide an updated synthesis of PFAS monitoring data in the Bay, identification of priority information gaps needed to inform monitoring and management, development of a conceptual model framework identifying source categories associated with pathways for PFAS to reach the Bay, and an updated strategy for RMP monitoring of PFAS.	A report (draft due March 2025, final due July 2025) that includes synthesis summary tables, interpretation of results in context of literature review and conceptual model, and recommended monitoring strategy. Project updates will also be presented at the 2024 and 2025 April ECWG meetings.
Emerging Contaminants	PFAS in Bay Water & Sediment using the TOP Assay	$67,200 (Dry & Wet Seasons; Water only)	Perfluoroalkyl and polyfluoroalkyl substances (PFAS) are fluorine-rich, chemically stable compounds widely used in consumer, commercial, and industrial applications, and are ubiquitous in the environment. Two of the most studied PFAS, perfluorooctanoic sulfonate (PFOS) and perfluorooctanoic acid (PFOA), are considered highly toxic, and other members of the class are predicted to have similar toxicity. The RMP has found PFAS in biota, water, and sediment as well as stormwater and wastewater. The RMP classifies PFAS as a Moderate Concern in the tiered risk-based framework due to concentrations in Bay biota linked to potential risks. A recently completed RMP analysis of PFAS in Bay water supported the continued prioritization of Bay monitoring for this class. However, most of the studies to date have focused on targeted methods analyzing up to 40 individual PFAS. The use of the total oxidizable precursors (TOP) assay provides a means to indirectly quantify a broad suite of PFAS precursors that break down to detectable compounds. This method has been used in recent Bay Area wastewater studies to demonstrate the presence of significant concentrations of unknown PFAS in this pathway. We propose a study to assess the levels of PFAS precursors in Bay water and sediment to supplement existing Status and Trends (S&T) monitoring of target PFAS and better characterize the presence of this class. Multiple options for sample collection are provided in response to potential constraints regarding Water and Sediment Cruise scheduling and available resources.	Develop sampling plan, field sampling (2023 dry season), lab analysis (2023 dry season), QA/QC, data management, preliminary findings presented to ECWG 2024, field sampling (2024 wet season), lab analysis (2024 wet season), QA/QC, data management, draft report, final report.
Emerging Contaminants	Non-targeted Analysis of San Francisco Bay Fish Year 1	$23,000 (Year 1 only)	Contaminants in sport fish may have both human health and ecological implications. The RMP has been monitoring selected contaminants in sport fish for many years but has never done any non-targeted analysis of this matrix. This two-year study would leverage 2024 Status and Trends sport fish monitoring to collect sport fish samples for non-targeted analysis. This type of analysis will provide a means to identify unanticipated contaminants that may merit follow-up targeted monitoring and compare San Francisco Bay fish contaminant profiles with those of fish from other locations such as the Great Lakes. Anticipated study outcomes would include priorities and recommendations for future investigations of newly identified CECs of potential concern observed in sport fish.	Develop sampling plan, sample collection, lab analysis, data analysis, presentations to ECWG & TRC, draft and final manuscripts/ RMP technical report.

Table 2: Short Descriptions of Proposals for RMP Special Studies in 2024

Workgroup	Study Name	Budget	Summary	Deliverables
Emerging Contaminants	PFAS and Nontargeted Analysis of Marine Mammal Tissues Year 2	$126,500	A recent review of the RMP Status and Trends (S&T) Monitoring Program design led to the recommendation to explore the addition of Bay marine mammals, such as harbor seals, to the species included in periodic S&T monitoring. To inform the potential inclusion of marine mammals to the long-term S&T program, this two-year study includes examination of PFAS in multiple tissues of two local species, harbor seals and harbor porpoises. This proposal adds nontargeted analysis of PFAS and hydrophobic halogenated compounds to the pilot study, providing a means to identify unanticipated contaminants that may merit follow-up targeted monitoring. Study outcomes would include recommendations for S&T monitoring of marine mammals, as well as priorities for future investigations of newly-identified CECs observed in marine mammal tissues. This proposal is for the second year of this two-year project.	Update sampling plan, sample collection, PFAS analysis, nontargeted analysis, draft manuscript, S&T study design recommendations (technical memo), presentation to TRC, final manuscript.
Microplastics	Microplastics in Stormwater Pilot	$65,800	To provide a better characterization of microplastics in stormwater and inform estimates on the magnitude of loads, and to support the State effort to develop standardized stormwater sampling methods, the proposed field study will start addressing these concerns by taking simultaneous point (single-depth) and depth integrated samples at two field sites during one storm each and comparing the microplastics content of these samples using advanced laboratory techniques that characterize tire wear and other fine particles.	Develop conceptual model and refine study design, site selection and field reconnaissance, sample collection, lab analysis, draft and final technical report.
Microplastics	Size Distribution of Microplastics	$65,000 - $105,000	This proposal would collect up to nine surface water samples and nine sediment samples from within San Francisco Bay. The particle size distribution of microplastics (>10 um) will be evaluated, including characterization of morphology and material. The particle size distributions measured from this proposal will be compared with particle size distribution models proposed and utilized by others. The amount of variation among and between sites will also be used to inform future microplastic monitoring design and exposure evaluations.	Develop study design, collect samples, lab analysis, draft and final manuscript submitted for publication.
Nutrients	Moored senson high-frequency observation network	$250,000	Bay-wide cruises have been critical to our understanding of the system. The Bay is spatially and temporally heterogeneous, however, and monthly measurements miss changes in water quality that are driven by short time scale processes, including tidal forcing, wind, and biological cycles. The eight sensors in the moored, high-frequency observation network in South Bay collect water quality data every 15 minutes and contribute to our understanding of Bay processes that affect nutrient and chlorophyll dynamics.	Sensor maintainace; data management
Sediment	Spatial variability of sediment accretion in San Francisco Bay restorations	$203,528	One of the key sediment management questions for San Francisco Bay is whether available sediment is sufficient to attain suitable elevations for marsh vegetation establishment and to keep pace with sea-level rise. Although large-scale restoration has been taking place in San Francisco Bay for decades, measurements of decadal-scale rates of accretion within areas where tidal exchange has been restored are limited. We propose to investigate accretion rates for a range of marsh restoration sites and estimate the volume of sediment in those sites. Our overall objectives are to 1) investigate the amount of accretion that has occurred within marsh restorations, 2) investigate the sediment characteristics in restorations, 3) estimate the mass and volume of sediment retained in these restorations; and 4) produce data sets for testing numerical models of sediment transport between the Bay and marsh restorations at 5 restoration marsh sites. Final site selection will be done in coordination with the RMP Sediment Workgroup and the WRMP and will depend on factors such as site accessibility and suitability for the study. Results will be useful for prioritizing marsh restoration sites, understanding bay-wide sediment budgets, and understanding sediment accretion in restorations region-wide, and their resilience to sea-level rise.	Data releases (September 2025); Draft report (March 2026); Presentation to the RMP (Spring or Fall 2026); Presentation to Bay Delta Science or State of the Estuary Conference (2026)
Sediment	Continuous Suspended Sediment Concentration and Wave Monitoring in South and Lower South San Francisco Bay - Year 3	$83,558	This proposed project would support continued data collection and calibration refinement for an additional seven months in 2024, which is needed to develop robust turbidity-SSC relationships. Once completed, these site-specific calibrations will expand continuous SSC monitoring to shallow areas of the SB and LSB, which play an important yet understudied role in Bay sediment dynamics. The collection of high frequency wave data will further inform sediment dynamics on the shoal, which are strongly influenced by wind waves. This project will support the maintenance of instruments and collection of SSC samples from the recently established SB shoal turbidity station directly offshore from Eden Landing, and collection of SSC samples at seven pre-existing turbidity stations, several of which have been collecting turbidity data since 2015.	15 minute SSC time series data release (summer 2024), Report detailing data collection and turbidity to SSC calculations (fall 2024), Presentation to the RMP Sed WG (spring 2025), Publicly available wave height and period data from one station South Bay (summer 2024).
Sediment	Sediment load from Bay area watersheds under future climate	$82,325	Sediment is a critical resource that is essential for sustaining San Francisco Bay tidal marshes and mudflats (or baylands) under a changing climate. “How will watershed load to the Bay change in relation to changing climate, vegetation cover, and land use?” is ranked as a high priority sub management question by Sediment Workgroup. With the development of the Bay regional watershed dynamic model (WDM), the impact of climate change on erosion and sediment transport processes in watersheds can now be assessed in a dynamic manner. We propose to use the WDM with downscaled climate model predictions to estimate sediment loadings from two operational landscape units (OLUs, Alameda, Napa and Sonoma) under 20 future climate scenarios. This will be coupled with a sensitivity analysis to assess the influence of vegetation cover and land use on sediment delivery downstream. The results of this study will help address SedWG's high-priority management questions, including: 'How will the load to the Bay from the watershed change in response to changing climate, vegetation cover, and land use?' The study will establish a link between watershed loads and sediment supply to downstream baylands that they will need to help them pace with sea-level rise (SLR).	Presentation at SedWG meeting (spring 2024), Technical report (winter 2024)

Table 2: Short Descriptions of Proposals for RMP Special Studies in 2024

Workgroup	Study Name	Budget	Summary	Deliverables
Sediment	Sediment Conceptual Model(s) for Individual San Francisco Bay Segments and Subembayments	Modular (min. $50,000 for one subembayment)	There is need for advancement of conceptual models that describe understanding of sediment delivery to and transport within Bay segments and subembayments, both now and into the future under a changing climate. These models will build upon the current San Francisco Bay sediment conceptual model that provides a high-level overview of current and predicted future delivery of sediment to and movement of sediment within all of San Francisco Bay. Bay segment and subembayment scale conceptual models will be based on and inform hypotheses regarding the dominant process controlling sediment supply and transport within a Bay segment and its subembayments and identify critical data needed to validate hypotheses and inform sediment management decisions.	Technical memo(s)/report(s)
Sources Pathways and Loadings	Integrated Monitoring and Modeling to Support PCBs and Mercury Watershed Loads Uncertainties Assessment and Monitoring Design	$220,000 for 2024, $160,000 for 2025	Continue integrated monitoring and modeling efforts on PCBs and Hg by conducting stormwater monitoring to support loads estimation, estimating model uncertainty, evaluating model sensitivities to parameters and data gaps, and providing PCBs and Hg monitoring design recommendations. There are two phases proposed. Addresses all five Management Questions (MQs).	WY 2024 samples collected, lab analysis, QA, & data management, draft Phase 1 report, final Phase 1 report, draft phase 2 report, final phase 2 report.
Sources Pathways and Loadings	Tidal Area Remote Sampler Pilot - Year 2	$62,000	Deploy the SFEI Mayfly - a remote sampler that addresses the challenges of sampling in tidal areas - at eight sites to capture water samples for PCB and Hg analysis. Will solidify our experience in field deployment of these samplers and an SOP will be developed to transfer to the municipalities. Primarily addresses MQ1.	Pilot test during rainy season, presentation to the SPLWG, data upload to CEDEN, draft report, final report.
Sources Pathways and Loadings	Pilot Study Using a Detection Dog Team for Source Tracing of PCBs in Old Industrial Areas of the San Leandro Bay Watershed	$25,000	Assess the feasibility of working with a detection dog to identify areas of high PCB concentrations in old industrial areas of the San Leandro Bay watershed. During a 2-week pilot deployment, SFEI will collect soil/caulking samples where the detection dog indicates elevated PCBs. Will provide insights into the validity of using this approach. Directly addresses MQ4 by identifying areas and properties with elevated PCBs for management action.	Project planning in consultation with Water Board, BAMSC - Task 1 BAMSC partnerships, survey areas, sample types & prior PCB costs - Task 2 Define scenarios with FieldLab LLC - Task 3 Presentations to Water Board, BAMSC, PCBWG, and SPLWG Draft Report Final Report
Sources Pathways and Loadings	Remote Sampler Purchase	$180,000	Funds the purchase of remote samplers for RMP stormwater work to support CECs monitoring in Bay Area watersheds and urban runoff monitoring in tidal zones. This proposal is a placeholder until this summer, when the Stormwater CECs Stakeholder-Science Advisor Team (SST) will decide on whether to use the SFEI Mayfly, the ISCO, or neither. Sampler purchase/construction will be done under the oversight of the SST.	Develop scope and budget, remote sampler purchase/construction.
Sources Pathways and Loadings	Watershed Dynamic Model (WDM) Maintenance	$50,000/yr	Funds maintenance of the Watershed Dynamic Model (WDM). Provides a list of tasks that can be done with the maintenance fund and proposes a process to decide on which of the maintenance activities and documentation are needed each year.	Proposed maintenance tasks, updated modeling log and new modeling output.
PCB	Priority Margin Unit Shiner Surfperch PCB Trend Monitoring	$20,000	Repeat sampling of PCBs in shiner surfperch in San Leandro Bay and Richmond Harbor stations is needed to track long-term trends in sport fish in support of management. Coordination with S&T sampling will yield significant savings in data management and reporting. A dataset for shiner surfperch will be obtained that is directly comparable across the PMUs and the other locations that are sampled in S&T.	Included in reporting of S&T sport fish.
PCB	Monitoring of Sediment Deposition in San Leandro Bay Intertidal Areas	$76,000	Horizon markers, temporary surface elevation tables, and sediment traps to characterize sedimentation processes near loading tributaries and in more ambient areas. Initial data from this effort is needed to support validation of a sediment transport and fate model for SLB planned for completion in Q2 of 2024	Technical report

Special Study Proposal: Stormwater Contaminants of Emerging Concern (CECs) Monitoring and Modeling 2024

Summary: This project will begin implementing the RMP stormwater CECs integrated modeling and monitoring program. The program framework is being developed through the RMP 2022 & 2023 “Stormwater CECs Approach” project that is slated for completion in late 2023. A second project currently underway, the 2023 “Stormwater CECs Monitoring Groundwork” project, is completing a series of necessary tasks to support development of robust, practical, and cost-effective systems for stormwater CECs monitoring. The Groundwork project feeds into the Stormwater CECs Approach development, which is being guided by a Stormwater CECs Stakeholder-Science Advisor Team (SST).

This proposal is a placeholder for completing and implementing the integrated modeling and monitoring program in wet season 2023/2024 (October 2023-September 2024) that will be defined by the Stormwater CECs Approach. It includes scopes and budgets for four specific tasks for which we request early release of funds to initiate implementation in summer 2023. It briefly outlines remaining tasks, which will be developed in concert with the completion of the Approach. These tasks will be developed under the oversight of the SST in parallel with the Approach and brought to the TRC and SC for approval.

Estimated Cost:	$300,000 RMP + $100,000 WQIF ($400K total; early release of RMP funds requested)
Oversight Group:	ECWG and SPLWG, Stormwater CECs Stakeholder-Science Advisor Team
Proposed by:	Kelly Moran, Tan Zi, Alicia Gilbreath, Rebecca Sutton
Time Sensitive:	Yes because it supports completion of the Stormwater CECs Approach and initiates implementation of the Stormwater CECs monitoring program in wet season 2023/2024.

PROPOSED DELIVERABLES AND TIMELINE

Deliverable	**Due Date**
Task 1. Scopes and budgets for remaining project tasks	Fall 2023-Spring 2024
Task 2. Stakeholder and science advisor engagement —Informal stakeholder and advisor meetings —SST meetings —Two RMP presentations (ECWG/SPLWG and SC/TRC) —Conference presentation	 Fall 2023-Fall 2024 Fall 2023-Summer 2024 Spring-Summer 2024 Fall 2024
Task 3. CECs Model Development Groundwork Reporting: General workplan for future phases of CECs modeling efforts (to be integrated into the Stormwater CECs Approach Draft Report)	Draft Fall 2023 Final Spring 2024
Task 4. Stormwater CECs work integrated scientific systems development and cross-task and cross-project team coordination	Fall 2023-Summer 2024
Remaining project tasks. Deliverables to be identified in task scopes	To be determined

Background

In 2022 and 2023 the RMP funded a two-year study to develop a stormwater CECs monitoring approach ("Stormwater CECs Approach"). Due to high CECs monitoring costs and technical challenges, a well-thought out, carefully focused approach is essential. Early work on the Approach project identified essential groundwork necessary to move forward with CECs monitoring in a robust, practical, and cost-effective manner. That groundwork is underway. Its schedule is driving the workflow and timing for completion of the Stormwater CECs Approach, slated for fall 2023.

This proposal complements a separate proposal for purchasing and/or building remote samplers capable of collecting stormwater during storm events. These samplers, which increase our sampling capacity and reduce sample collection cost, are a cornerstone of the Stormwater CECs Approach. That proposal is under the purview of the SPLWG, which will review it during its May 2023 meeting.

Study Objectives and Applicable RMP Management Questions

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

Management Question	Study Objective	Example Information Application
1) Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay?	N/A	N/A
2) What are the sources, pathways and loadings leading to the presence of individual CECs or groups of CECs in the Bay?	Design and implement CECs monitoring, including piloting new integrated modeling and monitoring approach and piloting use of remote samplers.	Implementing monitoring projects to address near-term priority stormwater CECs management questions, such as to determine whether stormwater pathway loads of various CEC families are large or small relative to other pathways flowing into the Bay.
3) What are the physical, chemical, and biological processes that may affect the transport and fate of individual CECs or groups of CECs in the Bay?	N/A	N/A
4) Have the concentrations of individual CECs or groups of CECs increased or decreased in the Bay?	Design and initiate monitoring capable of informing general understanding of changes in CECs presence in the stormwater pathway.	Understanding the changes in presence of CECs in the stormwater pathway.
5) Are the concentrations of individual CECs or groups of CECs predicted to increase or decrease in the future?	N/A	N/A
6) What are the effects of management actions?	N/A	N/A

Approach

We propose to pilot implementation of the new Stormwater CECs Monitoring Approach in wet season 2023/2024. A cornerstone of the Approach is the integration of modeling and monitoring designs to maximize the value of each sampling event. Consequently, this project proposal includes both monitoring and modeling.

Until the completion of the Approach this fall, details of the necessary work remain undetermined. This proposal is primarily a placeholder. It describes the general scope and nature of the work envisioned to pilot implementation of the Approach this winter. It includes complete scopes and budgets for four specific tasks for which we request early release of funds to initiate implementation in summer 2023. Remaining tasks, which are briefly outlined below, will be developed in concert with the Approach, under the oversight of the Stormwater CECs Stakeholder-Science Advisor Team (SST). The SST includes representatives from the Steering Committee and Technical Review Committee, as well as science advisors and stakeholders.

Task 1: Develop scopes and budgets for remaining project tasks

We will develop scopes and budgets for remaining tasks in concert with the Stormwater CECs Approach development, under the oversight of the SST. These will subsequently be provided to the SC for final approval. These will necessarily be developed in phases, with the early focus being to ensure that monitoring can occur in wet season 2023/2024 (e.g., pilot monitoring design and its implementation) and the later focus on the less time-sensitive elements (e.g., implementing the next phase of the multi-year phased modeling effort). Each task proposal will be presented in context of the overall project budget to ensure sufficient funds will be available for all priority tasks.

Task 2: Stakeholder and science advisor engagement

We will convene additional meetings of the SST to support this project in parallel with completion of the Stormwater CECs Monitoring Approach and to refine the program based on the pilot experience in wet season 2023/2024. We anticipate holding two or three SST meetings in addition to extensive informal individual and small group engagement with stakeholders and advisors as we finalize and pilot the Stormwater CECs Approach. We will provide a project update at spring 2024 RMP workgroup meeting(s) and plan to share findings at a stormwater or monitoring oriented conference such as the California Stormwater Quality Association (CASQA) Conference in fall 2024.

Task 3: CECs model development groundwork

The goals for this project element are to: 1) prepare a general workplan for CECs stormwater modeling efforts, 2) design the load modeling approaches and model structures for one pilot CEC, and 3) identify and verify model assumptions for the selected CEC (which will necessarily be quite different than those used for PCBs, mercury, and sediment) through literature review and monitoring data analysis. The outcome of this task, a general workplan for future phases of CECs modeling efforts, will be integrated into the Stormwater CECs Approach Draft Report, to be prepared in fall 2023.

Integrating CECs model development groundwork into this proposal will ensure the RMP will be able to move forward with its cost-saving and value-enhancing vision of integrating modeling with monitoring as it develops a CECs monitoring program. This task will also provide the modeling support necessary to complete the Stormwater CECs Approach Project in 2023.

<u>Task 4: Stormwater CECs Work Integrated Scientific Systems Development and Cross-Task and Cross-Project Team Coordination</u>
Project team meetings to keep this multi-faceted project on track, to develop operating systems (workflows and shared team physical and electronic resources) supporting the long-term implementation of integrated stormwater CECs modeling and monitoring, and to ensure consistency and coordination among the interlinked elements of this and related stormwater and Bay CECs monitoring and modeling projects. We anticipate (almost) biweekly high-level meetings with staff from the emerging contaminants, stormwater monitoring, modeling, project leadership, and RMP science leadership teams and occasional (every 2-3 months) meetings with a larger group of key scientific staff to work through scientific issues on specific project elements.

<u>Remaining tasks</u>
Our current vision is that the unbudgeted project funds would address the elements listed below, which will be developed in parallel with the completion of the Stormwater CECs Approach. The list could expand or change depending on the details of the Approach.

A. *Pilot implementation of the CECs monitoring approach,* which we anticipate to include:
    a. Develop a pilot monitoring design for wet season 2023/2024 consistent with the Stormwater CECs Monitoring Approach and addressing the near-term priority management questions. This task may include integration with Status & Trends monitoring design and identification of and site visits to reference site sampling locations.
    b. Sample collection, which includes activities like obtaining permits, installing remote samplers, collecting samples, and shipping the samples to the analytical laboratory.
    c. Chemical analysis for CEC parameters specified in the monitoring design.
    d. QA/QC review of data.
    e. Data interpretation at a level sufficient for use in evaluating outcomes and to inform future monitoring design. We do not anticipate a full report on the pilot year data, as we expect the Approach will establish a multi-year reporting and data interpretation process.

B. *Modeling*. Complete development of CECs model development plan and implement first year of that plan (CY 2024), which we anticipate to include:
   a. Prepare a specific load modeling plan for the selected pilot CEC;
   b. Prepare conceptual model for one high priority CEC approved by the SST.

C. *Potentially refine design of remote samplers and/or methods for their installation*, if these activities are not fully addressed in the separate remote samplers proposal to be reviewed by SPLWG.

Budget

The Project budget will include Labor, subcontract(s) (laboratories), and direct costs. Hours and costs for tasks not listed below will be estimated when the task scopes are developed.

Expense	Estimated Hours	Estimated Cost
Labor		
Task 1: Develop scopes and budgets for remaining project tasks	50	$10,000
Task 2: Stakeholder and science advisor engagement	220	$42,500
Task 3: CECs model development groundwork	379	$55,000
Task 4: Stormwater CECs work integrated scientific systems development and cross-task team coordination	175	$32,000
Remaining tasks	TBD	TBD
Laboratory and Other Direct Costs (Approximate)		
Laboratory		TBD
Equipment, sampling-related travel, shipping		TBD
Conference presentation travel		$2,000
Remaining tasks (primarily monitoring-related expenses)		$258,500
Grand Total		**$400,000**

<u>Budget Justification</u>

SFEI Labor
Labor hours for SFEI staff to complete all project elements.

Data Technical Services
Standard RMP data management procedures will be used. The monitoring design will specify whether data will be uploaded to CEDEN.

Laboratory Costs
Laboratory costs are anticipated to include analysis of field and QA/QC samples. Specific laboratory partner(s) will be identified in the task-specific scopes and budgets.

Other Direct Costs
Other direct costs are anticipated to include travel, shipping, and other miscellaneous sampling-related equipment. Estimates of other direct costs will be provided in the task-specific budgets. We anticipate purchasing or building the remote samplers to be used for this project under a separate project to be reviewed by SPLWG.

Early Funds Release Request
If this project is approved, we request early release of funds for use in 2023 to support parallel projects and to initiate monitoring during the 2023/2024 wet season.

Reporting

Reporting for Task 1, Scopes and budgets for remaining project tasks, will be the scopes and budgets presented for SST review and SC approval. Reporting for Task 2 will include summaries from SST meetings, the two RMP presentations, and the conference presentation. Reporting for Task 3, the CECs model development groundwork task, will be integrated into the Stormwater CECs Approach draft report to be completed in fall 2023 and final report to be completed by spring 2024.

Reporting for remaining tasks (e.g., presentations, written report[s]) will be determined in conjunction with the scope and budget for each task. Reporting may be combined with deliverables for other related projects.

Special Study Proposal: Tire and Roadway Contaminants in Wet Season Bay Water Year 3

Summary: 6PPD-quinone and other toxicologically relevant contaminants derived from tires have been observed in Bay Area stormwater and in wet season Bay water samples from 2021 and 2022. As part of its Status and Trends (S&T) program, the RMP is undertaking a pilot monitoring effort to quantify a number of contaminants in Bay water samples collected following storm events to provide information on the impact of stormwater discharges on Bay contaminant concentrations. This proposed study, the third and final year in a multi-year monitoring effort, would leverage the pilot S&T effort to evaluate more fully the concentrations of tire and roadway contaminants in Bay water during the wet season. Results will indicate whether these stormwater-derived contaminants reach concentrations of concern within receiving waters, filling a data gap relevant to the RMP's tiered risk-based framework for emerging contaminants. Results will be shared with the California Department of Toxic Substances Control's Safer Consumer Products Program, which seeks data to support its evaluation of tire chemical ingredients.

Estimated Cost:	$50,000
Oversight Group:	ECWG
Proposed by:	Ezra Miller, Kelly Moran, and Rebecca Sutton (SFEI); Ed Kolodziej (University of Washington)
Time Sensitive:	Yes, year three of multi-year study, leverages S&T pilot wet season water monitoring (2024)

PROPOSED DELIVERABLES AND TIMELINE

Deliverable	Due Date
Task 1. Update sampling plan	August – September 2023
Task 2. Field sampling – wet season Bay water samples	Fall 2023 – Spring 2024
Task 3. Lab analysis	Fall 2023 – Summer 2024
Task 4. QA/QC, data management, and data upload	October 2024
Task 5. Presentation at ECWG	April 2025
Task 6. Draft report	June 2025
Task 7. Final report	September 2025

Background

A number of potentially toxic tire-derived contaminants have been observed in Bay Area stormwater, including the salmonid toxicant, 6PPD-quinone, derived from a ubiquitously used tire preservative chemical (Tian et al. 2021; Brinkmann et al. 2022). Four of nine Bay Area stormwater samples collected in WY2019 contained levels of 6PPD-quinone that exceeded the coho salmon (*Oncorhynchus kisutch*) LC50, the concentration at which half the individuals die after a few hours of exposure in laboratory experiments. While coho salmon are now absent from Bay tributaries, steelhead (*Oncorhynchus mykiss*), a threatened species, are observed in some streams (e.g., Guadalupe River, Alameda Creek), and are similarly susceptible to toxic effects from this contaminant at concentrations somewhat higher than coho (Brinkmann et al. 2022; French et al. 2022). Another tire-derived contaminant, the rubber vulcanization agent 1,3-diphenylguanidine (DPG), was detected in stormwater at levels up to 1.8 µg/L (SFEI, unpublished data). This concentration approached the European Chemicals Agency predicted no effect concentrations (PNECs) for DPG of 30 µg/L in freshwater and 3 µg/L in marine waters (ECHA 2018). Monitoring of 6PPD-quinone, DPG, and other tire-derived contaminants is possible through a recently developed method designed to evaluate contaminants in stormwater (Hou et al. 2019).

To inform Status and Trends (S&T) sampling design, the RMP is piloting wet season water sampling to measure Bay concentrations of contaminants for which stormwater is a major transport pathway. Stormwater monitoring conducted by the RMP and others has shown that stormwater is a major pathway for prioritized emerging contaminants in the Bay, including bisphenols, organophosphate esters (OPEs), and per- and polyfluorinated alkyl substances (PFAS) (Houtz and Sedlak 2012; Sutton et al. 2019; SFEI, unpublished data). Sampling for these contaminants in both wet and dry seasons is important for understanding how different pathways contribute to Bay concentrations throughout the year and how those concentrations, and potential risks to aquatic life, vary spatially and temporally based on the dominant pathway. Prior to 2021, wet season water sampling had not been conducted by the RMP since 2010 and sites were restricted to deep Baystations far from stormwater inputs.

Tire-derived contaminants have only been monitored in Bay water during fall 2021 and in the first two years of the pilot S&T wet season monitoring (fall 2022 through spring 2023). These limited data suggest that tire-derived contaminants appear in the Bay in the wet season and potentially persist for many days after a storm event. These results are in distinct contrast to limited detections in dry season samples, indicating the importance of wet season monitoring. Dry season sampling (a single cruise) did not detect 6PPD-quinone and detected only traces (< 20 ng/L) of the other tire-derived contaminants. These chemicals have not yet been classified within the RMP's tiered risk-based framework for emerging contaminants (Sutton et al. 2017).

To build on previous RMP stormwater monitoring and to more fully understand the occurrence of tire contaminants in the Bay, we propose a follow-up study to continue to leverage the third year of the pilot S&T wet season monitoring effort to evaluate concentrations of tire-derived compounds in Bay water. Due to the low concentrations measured in the 2021 dry season, this project would not include any additional dry season monitoring for tire-related contaminants.

Results will inform the classification of these contaminants within the tiered risk-based framework and will be shared with the California Department of Toxic Substances Control's (DTSC) Safer Consumer Products Program, which seeks data to support its evaluation of tire chemical ingredients, and indicate whether further information is needed to assist water quality management decision-making. Should one or more of these contaminants be classified as Moderate Concern for the Bay, it may be appropriate to continue wet season monitoring via S&T activities. Because this project addresses a group of chemicals uniquely present in urban stormwater, these data may also be used to inform RMP watershed and Bay modeling projects currently underway.

Study Objectives and Applicable RMP Management Questions

The purpose of this study is to assess the concentrations of tire-derived contaminants in Bay water to improve our understanding of risks to aquatic life. These compounds may then be classified within the RMP's tiered, risk-based framework. The framework provides guidance on the need for additional monitoring and science to inform management of individual emerging contaminants and contaminant classes.

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

Management Question	Study Objective	Example Information Application
1) Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay?	Monitor tire-derived contaminants and other stormwater-associated CECs in Bay water.	Do these compounds have the potential to cause impacts to aquatic life? Which compounds are of greatest concern?
2) What are the sources, pathways, and loadings leading to the presence of individual CECs or groups of CECs in the Bay?	Evaluate concentrations in Bay water relative to stormwater.	Are Bay water concentrations near stormwater and wastewater-influenced sites consistent with the hypothesis that stormwater is the dominant pathway?
3) What are the physical, chemical, and biological processes that may affect the transport and fate of individual CECs or groups of CECs in the Bay?	Compare concentrations in near-field versus mid-Bay sites.	Are these stormwater-derived contaminants rapidly removed from Bay water?
4) Have the concentrations of individual CECs or groups of CECs increased or decreased in the Bay?	Monitor tire-derived contaminants and other stormwater-associated CECs in Bay water.	Establish a baseline for future trend analysis.
5) Are the concentrations of individual CECs or groups of CECs predicted to increase or decrease in the future?	N/A	N/A
6) What are the effects of management actions?	N/A	N/A

Approach

Bay Water Sampling

The RMP S&T water monitoring design was updated in 2022 to include wet season monitoring to measure concentrations of urban runoff-associated CECs in the Bay when the stormwater pathway is active. This project will involve collection of additional water samples in conjunction withplanned S&T monitoring.

All samples will be whole, unfiltered water collected using a stainless steel bailer, consistent with the prior Bay wet season water sample collection efforts.

Samples will be collected at three in-Bay stations near stormwater inputs (two storm events) plus one station near wastewater input (for contrast, one storm only) shortly following appropriately-sized storms, including the first flush if possible (Figure 1 green dots). In total, during the 2023-2024 wet season, we anticipate collecting a total of seven samples from the in-Bay near-field pathway sites, not including field blanks and duplicates. For stormwater sampling in the watershed, SFEI generally uses at least 0.5 inches of rain in six hours as its sampling criterion. Sampling at the in-Bay stations will be completed within two tidal cycles of the storm at locations meeting this criterion.

Samples will also be collected at four deep Bay stations (Figure 1 blue dots) within three weeks of at least one of the same storms sampled at the near-field locations. In total, during the 2023-2024 wet season, we anticipate collecting a total of four samples from the deep Bay stations, not including field blanks and duplicates.

QA/QC samples collected will include at least two field duplicates and two field blanks. Samples will be shipped overnight to Dr. Kolodziej at the University of Washington for LC/MS/MS analysis.

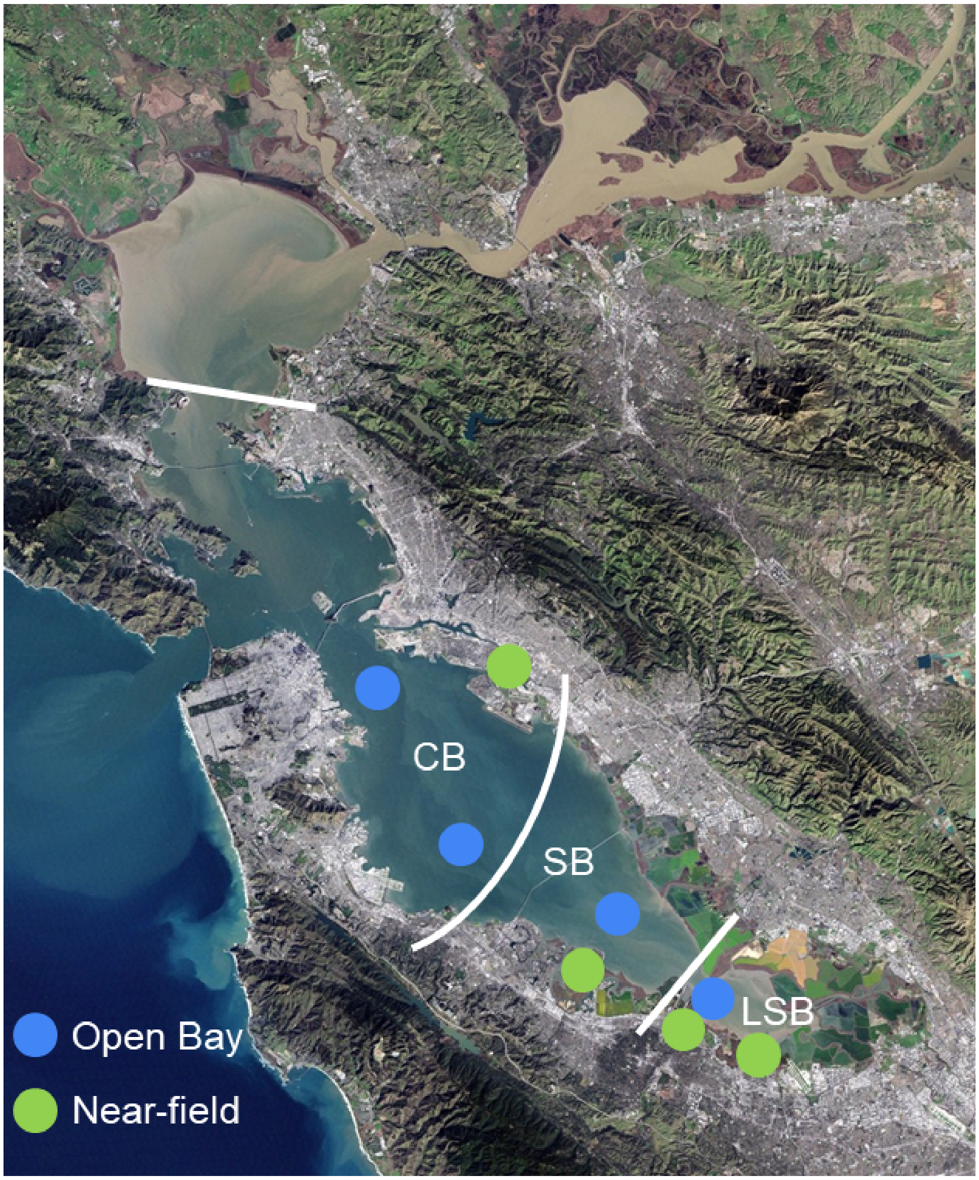

Figure 1. Proposed station selection for pilot wet season Status and Trends monitoring effort for water year 2024. Blue circles identify deep Bay stations; green circles identify in-Bay near-field stations (near San Leandro Creek, Redwood Creek, Stevens Creek, and Palo Alto municipal wastewater outfall). CB – Central Bay; SB – South Bay; LSB – Lower South Bay.

<u>Analytical Methods</u>

Unfiltered samples will be analyzed by the Kolodziej Laboratory (University of Washington) with a newly developed, targeted analytical method using multi-residue solid phase extraction (SPE) and liquid chromatography with tandem mass spectrometry (LC-MS/MS; Hou et al. 2019). A broad range of compounds will be monitored, including pharmaceuticals, pesticides, and several tire-derived analytes such as 6PPD-quinone and DPG (Table 2). This suite of representative tracers for urban runoff includes a broad range of contaminants with different physical-chemical parameters (e.g., various chemical functionalities, a wide range of polarities and biodegradation potential). The compounds were selected to represent three primary urban sources/pathways: residential use, roadways, and wastewater.

Table 2. Targeted analytes.

Analyte Group	**Analytes**
Tire-derived Compounds	1,3-diphenylguanidine (DPG) hexa-(methoxymethyl)melamine (HMMM) N-cyclohexyl-1.3-benzothiazole-2-amine (NCBA) 6PPD-quinone
Benzotriazoles	benzotriazole 5-methyl-1-H-benzotriazole 2-amino-benzothiazole 2-hydroxy-benzothiazole 2-(4-morpholinyl)-benzothiazole
Urban Use Pesticides	clothianidin imidacloprid thiamethoxam carbendazim iprodione diuron prometon
Pharmaceuticals and Personal Care Product Ingredients	caffeine cetirizine cotinine *N,N*-diethyl-*meta*-toluamide (DEET) triclosan
Commercial/Industrial Compounds	1,3-dicyclohexylurea

Budget

Table 3. Proposed Budget

Expense	Estimated Hours	Estimated Cost
Labor		
Study Design and Coordination (details for this project)	25	4,250
Stormwater Sample Collection (additional costs for this project)	25	3,500
Data Technical Services	35	5,000
Analysis and Reporting	100	22,500
Subcontracts		
University of Washington		10,000
Direct Costs		
Equipment		1,000
Shipping		3,750
Grand Total		**50,000**

Budget Justification

SFEI Labor
Labor hours are estimated for SFEI staff to manage the project, develop the study design details, support sample collection including shipping and coordination with the laboratory, review relevant literature, analyze and interpret data, present findings, and prepare a short stand-alone report.

Data Technical Services
Standard RMP data management procedures will be used for this project. Data will be uploaded to CEDEN.

Sample Collection
Costs are minimized through leveraging sample collection during the RMP S&T 2024 pilot wet season Bay water monitoring efforts.

Laboratory Costs (Ed Kolodziej, University of Washington)
Analysis of samples and associated QA/QC as well as assistance with data interpretation are included in a subcontract for $10,000.

Reporting

Results will be presented to the ECWG at the spring 2025 meeting; data will be incorporated into a report summarizing the data, evaluating the placement of tire-related chemicals into the CECs tiered, risk-based framework, and providing recommendations regarding future monitoring of tire chemicals. The report will be reviewed by the ECWG, TRC, and SC. Comments will be incorporated into the final report, due September 30, 2025.

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Special Study Proposal: Organophosphate Esters, Bisphenols, and Other Plastic Additives in Bay Area Wastewater

Summary: Plastic additives are an extensive group of chemicals used in the production of plastics for a variety of consumer, commercial, and industrial applications. Many of the chemical classes that comprise plastic additives, especially organophosphate esters (OPEs) and bisphenols, are ubiquitous in the environment. In addition, many of these compounds are known to be toxic and exhibit a variety of effects on humans and animals. The RMP has previously found OPEs and bisphenols in wastewater, stormwater, and ambient Bay water. The RMP currently classifies both as a Moderate Concern within the RMP tiered risk-based framework for emerging contaminants. To build on these previous efforts, we propose a study to assess the concentrations of OPEs, bisphenols, and other plastic additives in Bay Area wastewater effluent. Analysis of OPEs is a particularly high priority to allow for an assessment of the relative importance of stormwater versus wastewater pathways to the Bay. Leveraging a study of OPEs to include other plastic additives is a cost-effective way to gain more information on a broader list of widely used and potentially toxic compounds.

Estimated Cost:	Monitor OPEs, Bisphenols, & Plastic Additives in Effluent: $95,400 Monitor OPEs *Only* in Effluent: $48,400
Oversight Group:	ECWG
Proposed by:	Miguel Méndez, Rebecca Sutton
Time Sensitive:	No

PROPOSED DELIVERABLES AND TIMELINE

Deliverable	Due Date
Task 1. Develop Sampling Plan	June 2024
Task 2. Field Sampling – Wastewater	August - Sept. 2024
Task 3. Lab Analysis	March 2025
Task 4. QA/QC and Data Management	June 2025
Task 5. Draft Report	September 2025
Task 6. Final Report	January 2025
Task 7. Presentation at ECWG	April 2026

Background

Plastic additives are an extensive group of chemicals, and can include antioxidants, flame retardants, plasticizers, UV stabilizers, and several other compounds (Chen et al., 2021). Many plastic additives share physical and chemical properties such as high hydrophilicity and mobility in the environment, which make them more difficult to remove via traditional wastewater treatment methods, leading to contamination of receiving waters. Plastic additives enter the environment through several different pathways from their substantial consumer and industrial uses, notably from wastewater and stormwater.

As some of the plastic additives manufactured and used in the greatest quantities globally, organophosphate esters (OPEs) are found ubiquitously in the environment. OPEs have emerged as a new generation of flame retardants due to the phase-out of polybrominated diphenyl ethers (PBDEs). Triester OPEs (tri-OPEs) are the most commonly used and studied, though diester variations (di-OPEs) are also observed and are metabolites of tri-OPEs. OPEs have been linked to many toxic effects such as endocrine disruption, neurotoxicity, adverse fertility effects, and carcinogenicity, with three OPEs—tris(2-chloroethyl) phosphate (TCEP), tris(2,3-dibromopropyl)phosphate (TDBPP), tris(1,3-dichloro-2-propyl) phosphate (TDCPP)—listed as carcinogens on California’s Proposition 65 List (OEHHA, 2023; Wei et al., 2015). Still, the full scope of toxicity of OPEs, particularly for di-OPEs, is not completely understood.

Bisphenols are another well-known class of plastic additives with similar properties to OPEs. They have also been detected ubiquitously in the environment due to their widespread production and use. Bisphenol A (BPA), the best studied of the bisphenols, has been shown to have estrogenic effects, and is on California’s Proposition 65 List due to its developmental toxicity and female reproductive toxicity (Björnsdotter et al., 2017; OEHHA, 2023).

In 2017, the RMP biennial Status and Trends water cruise included analysis of 22 OPEs and 16 bisphenols in samples collected from 22 sites throughout the Bay during the dry season (Shimabuku et al., 2022). A pro bono add-on included preliminary characterization of 18 other plastic additives. Fifteen of 22 OPEs were detected, with six found in 100% of samples. The sum of all OPEs ranged from 35-290 ng/L (median 100 ng/L) across all Bay sites. In particular, concentrations of TDCIPP ranged from 2.8-23 ng/L, in the range of or above the marine predicted no effect concentration (PNEC) of 0.46 ng/L at many Bay sites (Xing et al., 2019). These detections were consistent with a previous screening study of flame retardants in surface water, sediment, bivalves, and harbor seal blubber conducted in 2013, which reported exceedances of toxicity thresholds for both TDCIPP and triphenyl phosphate (TPhP; Sutton et al., 2019).

Only BPA and bisphenol S (BPS) were quantified in 91% and 41% of sites, respectively, of the 16 bisphenols analyzed. Total concentrations of BPA (sum of particulate and dissolved contributions) ranged from <0.7–35 ng/L, while concentrations BPS ranged from <1–120 ng/L. These levels of bisphenols are in the range of a PNEC for BPA, 60 ng/L. Based on these findings, along with available toxicity data and potential for increasing use, OPEs and bisphenols have been classified as Moderate Concern within the RMP tiered risk-based framework for emerging contaminants.

All 18 additional plastic additives were detected in the 2017 survey, with 9 of 10 analyzed found in greater than 50% of samples. The sum of all additional plastic additives detected ranged from 220-3800 ng/L (median: 940 ng/L) across all Bay sites. One additive, tri(2-ethylhexyl) trimellitate (TOTM; also known as tris(2-ethylhexyl)benzene- 1,2,4-tricarboxylate) exceeded its marine PNEC of 6 ng/L at four sites, with a maximum concentration over an order of magnitude higher than its PNEC. Aquatic toxicity information as well as environmental occurrence data for many of these compounds is limited.

Several studies have identified wastewater and stormwater as important pathways of OPEs and bisphenols. A previous 2014 study of OPEs (Sutton et al., 2019) included a pilot evaluation in effluent from three wastewater treatment plants (WWTPs); 12 of 13 analytes were detected. The sum of all OPEs ranged from 3100-7900 ng/L with tris(1-chloro-2-propyl)phosphate (TCPP) and tris(2-butoxyethyl) phosphate (TBOEP) showing significantly higher levels compared to other analytes. A 2020 study of bisphenols in wastewater effluent from six wastewater treatment facilities detected 5 of 17 bisphenols (Mendez et al., 2022). BPA, BPF, and BPS were predominantly detected and the sum of bisphenols for all WWTP effluent samples had median and maximum concentrations of 96 and 246 ng/L. OPEs and bisphenols have also been detected in stormwater with further screening anticipated to better understand the importance of this pathway to Bay contamination. Other plastic additives have not been previously measured in local wastewater or stormwater, though based on these limited findings, they are likely to also be found in these pathways.

This proposal outlines a study to monitor OPEs, bisphenols, and additional plastic additives in wastewater effluent to continue building our understanding of pathways of these contaminants to the Bay. The results of this study can be compared to previous monitoring in wastewater and Bay water as well as forthcoming stormwater data to understand the relative influence of these pathways to the Bay. Analysis of OPEs is a particularly high priority to fill the data gap concerning effluent concentrations and loads, essential for an assessment of the relative importance of stormwater versus wastewater pathways to the Bay. The results from this study will further inform and refine the placement of OPEs, bisphenols, and other plastic additives in the RMP's tiered risk-based framework.

Study Objectives and Applicable RMP Management Questions

The purpose of this study is to assess the concentrations of OPEs, bisphenols, and additional plastic additives in wastewater effluent to improve our understanding of the sources and pathways of these contaminants into the Bay. Since pathways generally contain higher concentrations of contaminants due to their more direct connection to sources in urban settings, wastewater is an ideal matrix for early and broad detection of compounds that have been more recently incorporated into consumer and industrial products. Comparisons to concentrations measured in previous years in wastewater effluent will aid in this analysis. Comparing concentrations and estimated loadings for the wastewater and stormwater pathways can identify the relative importance of these pathways to Bay contamination. This study will expand analysis of OPEs, including di-OPEs, and can also include many additional plastic additives including bisphenols and others.

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

Management Question	Study Objective	Example Information Application
1) Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay?	N/A	N/A
2) What are the sources, pathways and loadings leading to the presence of individual CECs or groups of CECs in the Bay?	Characterize levels of OPEs, bisphenols, and other plastic additives in effluent	Concentrations and estimated loadings from effluent can be compared to similar values from stormwater to assess the relative importance of these pathways to the Bay. The presence of different CECs in each pathway may provide clues as to potential sources.
3) What are the physical, chemical, and biological processes that may affect the transport and fate of individual CECs or groups of CECs in the Bay?	N/A	N/A
4) Have the concentrations of individual CECs or groups of CECs increased or decreased in the Bay?	Comparison to previous studies of OPEs and bisphenols in wastewater effluent.	Analysis of time trends related to concentrations and/or loadings of OPEs and bisphenols in effluent. This study will provide baseline information that can be used to evaluate changes with time for other plastic additives.
5) Are the concentrations of individual CECs or groups of CECs predicted to increase or decrease in the future?	N/A	N/A
6) What are the effects of management actions?	N/A	N/A

Approach

Wastewater Effluent Sampling

The primary goal will be to assess dominant effluent flows to the Bay. We propose to do this by collecting effluent from the six largest wastewater treatment facilities: Central Contra Costa Sanitary District (CCCSD), East Bay Dischargers Authority (EBDA), East Bay Municipal Utility District (EBMUD), Palo Alto Wastewater Treatment (PA), and San Jose-Santa Clara Regional Wastewater Facility (SJSC). These facilities account for ~70% of wastewater effluent flows to the Bay. At each facility, 24-hour composites of effluent will be collected into glass containers twice during Fall 2024. Samples will be collected during the week to avoid any variation from the weekend.

Analytical Methods

Samples will be analyzed by Dr. Da Chen's laboratory (at Jinan University and Southern Illinois University), which previously analyzed bisphenols and OPEs in Bay water, as well as bisphenols in wastewater samples. Dr. Chen's team will use their existing water method, which uses a Shimadzu HPLC coupled to an AB Sciex 5500 Q Trap MS/MS (Toronto, Canada). This method can include analysis of up to 160 plastic additives, including a suite of 24 OPEs, 16 bisphenols, 41 phthalates, 10 non-phthalate plasticizers, 40 antioxidants, and 29 UV stabilizers (Chen et al., 2021).

Table 2. OPEs, bisphenols, and other plastic additives analytes included in prior study (Chen et al., 2021); specific analyte list may be refined as part of study design.

Group	Analyte	Full Name
Organophosphate Esters	BPA-BDPP	Bisphenol A bis(diphenylphosphate)
	BPDPP	t-butylphenyl diphenyl phosphate
	CDP	Cresyl diphenyl phosphate
	EHDPHP	2-Ethylhexyl-diphenyl phosphate
	IDDPP	Isodecyl diphenyl phosphate
	RDP	Resorcinol bis(diphenyl phosphate)
	T2IPPP	Tris(2-isopropylphenyl) phosphate
	T35DMPP	Tris(3,5-dimethylphenyl) phosphate
	TBOEP	Tris(2-butoxyethyl) phosphate
	TBP	Tributyl phosphate
	TCEP	Tris(2-chloroethyl) phosphate
	TCIPP	Tris(2-chloroisopropyl) phosphate
	TCrP	Tricresyl phosphate
	TDBPP	Tris(2,3-dibromopropyl) phosphate
	TDCIPP	Tris(1,3-dichloro-2-propyl) phosphate

Group	Analyte	Full Name
Organophosphate Esters	TEHP	Tris(2-ethylhexyl) phosphate
	TEP	Triethyl phosphate
	TPhP	Triphenyl phosphate
	TPrP	Tripropyl phosphate
	V6	Tetrakis(2-Chloroethyl)dichloroisopentyldiphosphate
Bisphenols	BPA	4,4'-(1-Methylethylidene) bisphenol
	BPAF	4,4'-(Hexafluoroisopropylidene) diphenol
	BPAP	4,4′-(1-Phenylethylidene) bisphenol
	BPB	4,4'-(1-Methylpropylidene) bisphenol
	BPBP	4,4'-(Diphenylmethylene) diphenol
	BPC	2,2-Bis(4-hydroxy-3-methylphenyl) propanone
	BPC-dichloride	4,4'-(2,2-Dichlorovinylidene)bisphenol
	BPE	4,4'-Ethylidenebisphenol
	BPF	4,4'-Methylenebisphenol
	BPG	4-[2-(4-hydroxy-3-propan-2-yl-phenyl)propan-2-yl]-2-propan-2-yl-phenol
	BPM	4,4′-(1,3-Phenylenediisopropylidene) bisphenol
	BPP	4,4'-[1,4-Phenylenebis(1-methylethane-1,1-diyl)] bisphenol
	BPPH	5,5'-Isopropylidenebis(2-hydroxybiphenyl)
	BPS	Bis(4-hydroxyphenyl) sulfone
	BP-TMC	4,4'-(3,3,5-Trimethyl-1,1-cyclohexanediyl) bisphenol
	BPZ	4,4'-Cyclohexylidenbisphenol
Phthalates	BBzPh	Butylbenzyl phthalate
	iBCHPh	Isobutylcyclohexyl phthalate
	DAPh	Diallyl phthalate
	DBPh	Di-n-butyl phthalate
	DiBPh	Diisobutyl phthalate
	DiBzPh	Dibenzyl phthalate
	DiDPh	Diisodecyl phthalate
	DEPh	Diethyl phthalate
	DEHPh	Bis(2-ethylhexyl) phthalate
	BMPPh	Bis(4-methyl-2-pentyl) phthalate
	DHPh	Dihexyl phthalate
	DiHPh	Diisohexyl phthalate
	DNPh	Dinonyl phthalate
	DiNPh	Diisononyl phthalate
	DPePh	Di-n-pentyl phthalate

Group	Analyte	Full Name
Phthalates	DiPePh	Diisopentyl phthalate
	DPhPh	Diphenyl phthalate
	DPiPh	Diphenyl isophthalate
	DPrPh	Di-n-propyl phthalate
	DiPrPh	Diisopropyl phthalate
	DUPh	Diundecyl phthalate
Mono-phthalates	MBPh	Mono-n-butyl phthalate
	MiBPh	Monoisobutyl phthalate
	MBzPh	Monobenzyl phthalate
	MCHPh	Monocyclohexyl phthalate
	MEPh	Monoethyl phthalate
	MEHPh	Monoethylhexyl phthalate
	MHePh	Mono-2-heptyl phthalate
	MHxPh	Monohexyl phthalate
	MiNPh	Monoisononyl phthalate
	MOPh	Mono-n-octyl phthalate
	MPePh	Mono-n-pentyl phthalate
	MiPrPh	Monoisopropyl phthalate
	MEHHPh	Mono (2-ethyl-5-hydroxyhexyl) phthalate
	MEOHPh	Mono (2-ethyl-5-oxohexyl) phthalate
	MCPPh	Mono (3-carboxypropyl) phthalate
Non-phthalate plasticizers Non-phthalate plasticizers	ATBC	Acetyl tri-n-butyl citrate
	DiBA	Diisobutyl adipate
	DBA	Dibutyl adipate
	DiDeA	Diisodecyl adipate
	DiDeAz	Diisodecyl azelate
	DEHA	Bis(2-ethylhexyl) adipate
	DHeNoA	Di(n-heptyl,n-nonyl) adipate
	DINCH	Di-isononylcyclohexane-1,2-dicarboxylate
	TCaT	Tricapryl trimellitate
	TOTM	Trioctyl trimellitate
UV stabilizers: benzothiazoles	2-Me-BTH	2-Methylbenzothiazole
	2-Mo-BTH	2-(Morpholinothio)-benzothiazole
	2-Me-S-BTH	2-(Methylthio)-benzothiazole
	2-OH-BTH	2-Hydroxybenzothiazole

Group	Analyte	Full Name
UV stabilizers: benzotriazoles	1-H-BTR	1-Hydrogen-benzotriazole
	5-Cl-BTR	5-Chloro-benzotriazole
	5-Me-1-H-BTR	5-Methyl-1-hydrogenbenzotriazole
	1-OH-BTR	1-Hydroxybenzotriazole
	UV-234	2-(2H-benzotriazol-2-yl)-4,6-bis(1-methyl-1-phenylethyl)phenol
	UV-320	2-(3,5-Di-tert-butyl-2-hydroxyphenyl) 2H-benzotriazole
	UV-326	2-Tert-butyl-6-(5-chloro-2H-benzotriazol-2-yl)-4-methylphenol
	UV-327	2,4-Di-tert-butyl-6-(5-chloro-2H-benzotriazol-2-yl)phenol
	UV-328	2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol
	UV-350	2-(3-Sec-butyl-5-tert-butyl-2-hydroxyphenyl)benzotriazole
	UV-P	2-(2-Hydroxy-5-methylphenyl) benzotriazole
	UV-PS	2-(5-Tert-butyl-2-hydroxyphenyl) benzotriazole
UV stabilizers: benzophenone	BP1	2,4-Dihydroxybenzophenone
	BP3	2-Hydroxy-4-methoxybenzophenone
	BP4	2-Hydroxy-4-methoxybenzophenone-5-sulfonic acid hydrate
	BP6	2,2-Dihydroxy-4,4-dimethoxybenzophenone
	BP8	2,2′-Dihydroxy-4-methoxybenzophenone
	4-OH-BP	4-Hydroxybenzophenone
UV stabilizers: others	4-MBC	3-(4-Methylbenzylidene) camphor
	BMDM	4-Tert-Butyl-4′-methoxydibenzoylmethane
	IAMC	Isoamyl 4-methoxycinnamate
	OC	2-Ethylhexyl 2-cyano-3,3-diphenyl-2-propenoate
	ODPABA	Octyl dimethyl-p-aminobenzoic acid
	OMC	Ethylhexyl methoxycinnamate
Antioxidants	BHA	2(3)-Tert-butyl-4-hydroxyanisole
	BHT-OH	2,6-Di-tert-butyl-4-(hydroxymethyl)phenol
	BHT-CHO	3,5-Di-tert-butyl-4-hydroxybenzaldehyde
	BHT-COOH	3,5-Di-tert-butyl-4-hydroxybenzoic acid
	3,5-DTBH	11-Methyldodecyl3-[4-hydroxy-3,5-bis(2-methyl-2-propanyl)pheny]propanoate
	4-tOP	4-(1,1,3,3-Tetra-methylbutyl)phenol
	AO245	hydroxy-3-methyl-5-(2-methyl-2-propanyl)phenyl]propanoate}
	AO259	1,6-Hexanediylbis{3-[4-hydroxy-3,5-bis(2-methyl-2-propanyl)phenyl]propanoate}
	AO425	2,2'-Methylenebis(4-ethyl-6-tert-butylphenol)
	AO565	4-[[4,6-Bis(octylsulfanyl)-1,3,5-triazin-2-yl]amino]-2,6-ditert-butylphenol

Group	Analyte	Full Name
Antioxidants	AO697	(1,2-Dioxo-1,2-ethanediyl)bis(imino-2,1-ethanediyl)bis{3-[4-hydroxy-3,5-bis(2-methyl-2-propanyl)phenyl]propanoate}
	AO1035	Sulfanediyldi-2,1-ethanediylbis{3-[4-hydroxy-3,5-bis(2-methyl-2-propanyl)phenyl]propanoate}
	AO1081	2,2'-Thiobis(6-tert-butyl-p-cresol)
	AO1098	N,N'-1,6-Hexanediylbis{3-[4-hydroxy-3,5-bis(2-methyl-2-propanyl)phenyl]propanamide}
	AO1222	Diethyl 3,5-di-tert-butyl-4-hydroxybenzyl phosphonate
	AO2246	2,2'-Methylenebis(6-tert-butyl-4-methylphenol)
	AO3790	Tris(4-tert-butyl-3-hydroxy-2,6-dimethylbenzyl)isocyanurate
	AO22E46	2,2'-(1,1-Ethanediyl)bis[4,6-bis(2-methyl-2-propanyl)phenol]
	AO44B25	4,4'-Butylidenebis(6-tert-butyl-m-cresol)
	AO-TBM6	4,4'-Thiobis(6-tert-butyl-m-cresol)
	diAMS	Bis[4-(2-phenyl-2-propyl)phenyl]amine
	DBHA	Dibenzylhydroxylamine
	DET	N,N'-diethylthiourea
	DTG	1,3-Di-o-tolylguanidine
	DPG	1,3-Diphenylguanidine
	DPT	1,3-Diphenyl-2-thiourea
	DPPD	N,N'-Diphenyl-1,4-benzenediamine
	PANA	N-Phenyl-1-naphthylamine
	BBOT	2,2'-(2,5-Thiophenediyl)-bis(5-tert-butylbenzoxazole)
	MMBI	Methyl-2-mercaptobenzimidazole

Budget

Table 3. Budget

Expense	Estimated Hours (Range)	OPEs, Bisphenols, & Plastics Additives	OPEs Only
Labor			
Study Design	20	$2,800	$2,800
Sample Collection	40	$5,600	$5,600
Data Technical Services		$10,000	$6,200
Analysis and Reporting	120-250	$35,000	$16,800
Subcontracts			
Dr. Da Chen, Jinan/SIU		$35,000	$11,200
Direct Costs			
Equipment		$1000	$500
Travel		$2,000	$2,000
Shipping		$4,000	$2,500
Grand Total		**$95,400**	**$48,400**

Budget Justification

SFEI Labor
Labor hours are estimated for SFEI staff to manage the project, develop the study design, support sample collection, analyze data, review toxicological risks, present findings, and write a report including recommendations on future related monitoring.

Data analysis can include examination of any temporal trends, spatial trends, and investigation into the influence of wastewater and stormwater on noted concentrations and estimated loadings in the Bay. Costs for sample collection include SFEI staff assisting facilities to collect samples.
Data and Technical Services
To minimize costs, data will undergo RMP QA/QC review and be formatted for CEDEN but not uploaded.

Laboratory Costs (Dr. Da Chen, Jinan/SIU)
Analytical costs per sample are estimated at $700 for only OPEs and ~$2,190 for all analytes. For 12 field samples of only OPEs monitoring, with two field duplicates and two field blanks, the total analytical cost is $11,200. For monitoring of OPEs, bisphenols, and plastic additives, 16 samples would total $35,000.

Reporting

A draft report will be prepared by 09/31/25 and be reviewed by the ECWG and TRC. Comments will be incorporated into the final report, published by 1/31/26. Full results will be presented to the ECWG at the spring 2026 meeting.

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Special Study Proposal: PFAS Synthesis and Strategy Revision

Summary: Per- and polyfluoroalkyl substances (PFAS) are a class of fluorine-rich chemicals that are used widely in industrial processes and consumer and industrial products, leading to widespread environmental contamination around the world. Since the previous RMP PFAS synthesis and strategy effort completed in 2018, the RMP has collected, and is in the process of collecting significant additional data and information about PFAS in the Bay and Bay pathways. Additionally, concerns relating to the persistence of PFAS, the high toxicity of well-studied members of this class, and the pattern of regrettable substitution observed in industry, have led scientific and regulatory bodies to recommend broad, class-based monitoring and management approaches. With these recent scientific and management developments, as well as the elevation of PFAS as a broader class in the RMP's tiered risk-based framework, an updated comprehensive synthesis of PFAS Bay monitoring data and a strategy for future monitoring is needed. This proposed synthesis and strategy revision would provide an updated synthesis of PFAS monitoring data in the Bay, identification of priority information gaps needed to inform monitoring and management, development of a conceptual model framework identifying source categories associated with pathways for PFAS to reach the Bay, and an updated strategy for RMP monitoring of PFAS.

Estimated Cost:	$107,000
Oversight Group:	ECWG
Proposed by:	Diana Lin, Ezra Miller, Kelly Moran, Rebecca Sutton
Time Sensitive:	Yes to inform ongoing state-wide PFAS monitoring and management strategies

PROPOSED DELIVERABLES AND TIMELINE

Deliverable	Due Date
Task 1. Presentation and discussion at ECWG to identify management drivers	April 2024
Task 2. Compile datasets, standardize, and conduct data analysis and evaluations	January - June 2024
Task 3. Concise literature review to inform data evaluations and strategy development	June - December 2024
Task 4. Draft Report	March 2025
Task 5. Gather comments on Draft Report strategy during ECWG	April 2025
Task 6. Final Report	July 2025

Background

Per- and polyfluoroalkyl substances (PFAS), a family of thousands of synthetic, fluorine-rich compounds commonly referred to as "forever chemicals," are known for their thermal stability, non-reactivity, and surfactant properties. All PFAS are highly persistent or, in the case of precursors, degrade to substances that are highly persistent. Some PFAS, particularly the long-chain compounds, bioaccumulate and are associated with a wide variety of toxic effects in wildlife and humans. These unique compounds have widespread uses across consumer, commercial, and industrial products, resulting in widespread occurrence in the environment and wildlife across the globe. However, data gaps remain on PFAS sources and environmental fate, as thousands of compounds are registered for use, yet fewer than 50 have been the subject of significant monitoring in environmental media (Wang et al., 2019).

Concerns relating to the persistence of PFAS, the high toxicity of well-studied members of this class, and the pattern of regrettable substitution observed in industry, have led scientific and regulatory bodies to recommend broad, class-based monitoring and management approaches. The RMP has followed that recommendation. Previously, long-chain PFAS like PFOS and PFOA were classified as Moderate Concern within the RMP's tiered risk-based framework, while all other PFAS were classified as Possible Concern (Sedlak et al., 2018). Reclassification of all PFAS as Moderate Concern was agreed upon during the 2020 ECWG meeting, consistent with the rapidly evolving scientific and regulatory response to PFAS as a broad class of priority compounds for management actions (Miller et al., 2020). Due to their Moderate Concern classification, the 2022 RMP Status and Trends (S&T) redesign added PFAS monitoring to every matrix; previously, PFAS were only monitored in bird eggs and sport fish as part of S&T monitoring.

Since the previous RMP PFAS synthesis and strategy effort (Sedlak et al., 2018), the RMP and RMP partners have collected or are in the process of collecting data on PFAS in many Bay matrices, including water (Mendez et al., 2022; ongoing), sediment (ongoing), sport fish (Buzby et al., 2019), prey fish (ongoing), bird eggs (ongoing), marine mammals (ongoing), wastewater (Mendez et al., 2021; ongoing), and stormwater (ongoing). Additionally, the RMP participated in a pro bono project to develop a multi-box mass balance model to predict the long-term distribution and concentrations of PFOS and PFOA in water, sediment, and fish (Sánchez-Soberón et al., 2020). These recent advances in our understanding of PFAS in San Francisco Bay matrices and pathways already go above and beyond the monitoring strategy outlined by Sedlak et al. (2018). Additionally, ongoing implementation of the State Water Board's PFAS Action Plan (https://www.waterboards.ca.gov/pfas/) has generated a wealth of PFAS data.

Management of PFAS has also changed to reflect the growing use of a class-wide approach since the 2018 RMP PFAS synthesis and strategy effort. In California, the Department of Toxic Substances Control's Safer Consumer Products Program has established a clear rationale for management actions directed at the entire PFAS class

(Bălan et al., 2021), and has begun to apply this approach, starting with carpets and rugs made or sold in California. Similarly, state bans on PFAS in paper-based food packaging and products intended for infants and children, both of which take effect in 2023, rely on a class-wide approach, rather than bans of individual compounds. At the federal level, the US EPA has adopted a PFAS Strategic Roadmap to begin to more fully address this complex class of contaminants. Management of PFAS as a class has also been recommended by several countries within the European Union, via a proposal to prohibit the production, marketing, and use of the class throughout Europe, with exceptions for essential uses such as medical applications.

With these recent scientific and management developments, as well as the elevation of PFAS as a broader class in the RMP's tiered risk-based framework, an updated comprehensive synthesis of PFAS Bay monitoring data and strategy for future monitoring is needed. This proposed synthesis and strategy revision would provide an updated synthesis of PFAS monitoring data in the Bay, identification of priority information needs to support monitoring and management, and an updated strategy for RMP monitoring of PFAS. Recommendations will also inform efforts beyond the RMP, including State and Regional Water Boards' monitoring and management strategies moving forward.

Study Objectives and Applicable RMP Management Questions

The purpose of this study is threefold. First, the project will provide an updated synthesis of existing Bay PFAS data collected by the RMP and other scientists into one document. This will allow better accessibility of recent PFAS data.

Second, this project will conduct a concise literature review to provide more context in evaluating Bay data, to inform monitoring design, and to identify priority information gaps for management of PFAS in the Bay.

Third, this project will propose a monitoring strategy for the RMP for PFAS that integrates with ongoing RMP modeling and monitoring work (e.g., integrated stormwater CECs modeling and monitoring, integrated Bay and watershed modeling, in-Bay fate modeling).

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

Management Question	Study Objective	Example Information Application
1) Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay?	- Synthesize various data sets and update risk evaluation - Identify monitoring data needs for RMP water quality managers to evaluate impacts	- What type of analytical methods (e.g., target, total oxidizable precursor, non-target) are needed to inform management decisions?
2) What are the sources, pathways and loadings leading to the presence of individual CECs or groups of CECs in the Bay?	- Synthesize recent data on stormwater and effluent pathways - Synthesis of relevant air monitoring data from other studies - Develop conceptual model for major sources and pathways of PFAS to the Bay -Summarize product categories likely associated with each transport pathway to the Bay	- What are PFAS levels in wastewater and urban stormwater runoff? - How important is air transport? - Is groundwater from contaminated sites a significant pathway to the Bay? - What are the priority information gaps to characterize major sources and pathways?
3) What are the physical, chemical, and biological processes that may affect the transport and fate of individual CECs or groups of CECs in the Bay?	- Summarize identified PFAS analytes in the environment - Identify new PFAS that have not been monitored in the Bay	- Where are the areas of greatest concern in the Bay?
4) Have the concentrations of individual CECs or groups of CECs increased or decreased in the Bay?	- Evaluate temporal trends in Bay matrices and pathways	- Do available monitoring data indicate an increasing or decreasing trend?
5) Are the concentrations of individual CECs or groups of CECs predicted to increase or decrease in the future?	- Summarize ongoing and anticipated management actions that may directly impact PFAS in the Bay	- What management actions will be most effective at reducing PFAS in the Bay?
6) What are the effects of management actions?	- Summarize ongoing and anticipated management actions that may directly impact PFAS in the Bay	- Will management actions have the intended effects? - Are management actions targeting the most important sources and pathways?

Approach

Synthesis

The synthesis will focus on studies from the last 10 years (2012-2023). Key datasets that will be compiled include monitoring data from Bay water, sediment, wastewater, stormwater, and biota. This will include the following RMP studies, which were conducted after the completion of the previous PFAS Synthesis (Sedlak et al., 2018).

- Bay water. Ambient Bay water samples collected in 2021 (Mendez et al., 2022). Additional deep Bay water and near-shore samples will be collected as part of the S&T program (dry season cruise 2023; WY2022-2024, as available).
- Sediment. Archived sediment collected from 2018 Status & Trends program and 2020 North Bay margins study (to be analyzed via a SEP-funded study). Additional sediment samples will be collected as part of the S&T program in 2023.
- Sport fish. Sport fish samples collected in 2019 (Buzby et al., 2019) and archived sport fish samples from 2009 - 2019 analyzed to evaluate trends.
- Prey fish. Samples will be collected in 2023 as part of the S&T program.
- Bird eggs. Samples collected in 2018 and 2022 as part of the S&T program.
- Marine mammals. Samples from 2023 that will be analyzed via targeted and non-target analysis.
- Stormwater. Stormwater samples collected during WY2020-2022 as part of RMP multi-year CEC stormwater screening study (Kolodjiez et al., in prep).
- Wastewater. Wastewater influent, effluent, biosolids, and sewershed samples collected winter of 2020 and summer of 2022 as part of BACWA PFAS Phase 1 (Mendez et al., 2021) and Phase 2 Study.

The synthesis will also compile available Bay monitoring data collected by others that are published in peer-reviewed journals and grey literature technical reports from reputable sources. In addition, we will evaluate whether it is appropriate to include available Bay data on fluorinated pharmaceuticals and pesticides, some of which may be considered PFAS.

Literature Review

A concise and focused literature review will be synthesized to put the Bay Area monitoring data in context and inform the monitoring strategy. The understanding gained through this review of the major pathways of PFAS contamination and PFAS product categories most likely associated with each pathway will be summarized in the context of a conceptual model framework. The targeted literature review will include the following components:

- Evaluation of Bay data in the context of monitoring data from other regions
- Summary of advances in analytical methods for monitoring PFAS
- Summary of published PFAS product categories and other sources (e.g., groundwater contamination) likely associated with each transport pathway to the Bay

- Summary of known and important transport and fate processes for each transport pathway and in the Bay itself
- Identification and prioritization of major information gaps relevant for monitoring and modeling design and management information needs.

Strategy

A monitoring strategy will be developed for the RMP within the context of, and integrated with, regional monitoring and modeling, and designed to provide science to support management efforts. The monitoring strategy will provide recommendations for study design (e.g., matrix, spatial distribution, frequency, and analytical methods) appropriate for answering a range of study questions relevant to stakeholder-identified management priorities. We will vet the proposed strategy with selected PFAS advisors (in addition to the existing set of ECWG advisors), as well as the ECWG and TRC.

Budget

Table 2. Budget

Expense	Estimated Hours	Estimated Cost
Labor		
Synthesis	140	$23,300
Literature Review and Strategy	255	$42,300
Reporting	220	$40,400
Honoraria		
2 science advisors		$1,000
Grand Total		**$107,000**

Budget Justification

Labor hours are estimated for SFEI staff to manage the project, gather input from stakeholders and advisors, synthesize RMP and peer-reviewed datasets, conduct literature review, develop monitoring strategy, and prepare deliverables.

Reporting

The deliverable will consist of a report (draft due March 2025, final due July 2025) that includes synthesis summary tables, interpretation of results in context of literature review and conceptual model, and recommended monitoring strategy. Project updates will also be presented at the 2024 and 2025 April ECWG meetings.

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Special Study Proposal: Per- and Polyfluoroalkyl Substances (PFAS) in Ambient Bay Water and Sediment using the Total Oxidizable Precursors (TOP) Assay

Summary: Perfluoroalkyl and polyfluoroalkyl substances (PFAS) are fluorine-rich, chemically stable compounds widely used in consumer, commercial, and industrial applications, and are ubiquitous in the environment. Two of the most studied PFAS, perfluorooctanoic sulfonate (PFOS) and perfluorooctanoic acid (PFOA), are considered highly toxic, and other members of the class are predicted to have similar toxicity. The RMP has found PFAS in biota, water, and sediment as well as stormwater and wastewater. The RMP classifies PFAS as a Moderate Concern in the tiered risk-based framework due to concentrations in Bay biota linked to potential risks. A recently completed RMP analysis of PFAS in Bay water supported the continued prioritization of Bay monitoring for this class. However, most of the studies to date have focused on targeted methods analyzing up to 40 individual PFAS. The use of the total oxidizable precursors (TOP) assay provides a means to indirectly quantify a broad suite of PFAS precursors that break down to detectable compounds. This method has been used in recent Bay Area wastewater studies to demonstrate the presence of significant concentrations of unknown PFAS in this pathway. We propose a study to assess the levels of PFAS precursors in Bay water and sediment to supplement existing Status and Trends (S&T) monitoring of target PFAS and better characterize the presence of this class. Multiple options for sample collection are provided in response to potential constraints regarding Water and Sediment Cruise scheduling and available resources.

Estimated Cost:	$97,700; Dry & Wet Season Sampling (Bay Water & Sediment) $67,200; Dry & Wet Season Sampling (Bay Water Only) $27,200; Wet Season Sampling Only (Bay Water Only); Multi-year
Oversight Group:	ECWG
Proposed By:	Miguel Méndez, Rebecca Sutton
Time Sensitive:	Yes, leveraging S&T water monitoring in 2023 and 2024.

PROPOSED DELIVERABLES AND TIMELINE

Deliverable	Due Date
Task 1. Develop Sampling Plan	July 2023[1]
Task 2. Field Sampling – Bay Water & Sediment (*Dry Season*)	August-Sept. 2023
Task 3. Lab Analysis (*Dry Season*)	December 2023
Task 4. QA/QC and Data Management (*Dry Season)*	February 2024
Task 5. Preliminary Findings Presented at ECWG	April 2024
Task 6. Field Sampling – Bay Water (*Wet Season*)	Winter-Spring 2024[2]
Task 7. Lab Analysis (*Wet Season*)	June 2024[2]
Task 8. QA/QC and Data Management (*Wet Season*)	August 2024[2]
Task 9. Draft Report	November 2024
Task 10. Final Report	February 2025

[1]*Due to the timing of the dry season cruise, an early indication of funding likelihood is needed to prepare for sampling.*
[2]*Rows in gray are additional tasks related to sampling during the wet season.*

Background

Per- and polyfluoroalkyl substances (PFAS), a family of thousands of synthetic, fluorine-rich compounds commonly referred to as “forever chemicals,” are known for their thermal stability, non-reactivity, and surfactant properties. These unique substances have widespread uses across consumer, commercial, and industrial products, resulting in widespread occurrence in the environment and wildlife across the globe. Their highly persistent and recalcitrant nature, coupled with potential bioaccumulation and toxicity risks, raise concerns of negative impacts on wildlife and human health.

PFOS and PFOA, the most well-studied PFAS, have been the regulatory focus based on their extensive toxicity profiles highlighting a range of toxic effects, multi-year half-lives in human blood, and bioaccumulation in aquatic food webs (DeWitt, 2015; Sunderland et al., 2019). In the US, production of PFOS was phased out by 2002, and production of PFOA was phased out by 2015. With the increasing use of replacements for these compounds, it is important to understand the greater breadth of PFAS in the environment, particularly through a focus on PFAS precursors. These are compounds, both known and unknown, that have the potential to form perfluorinated carboxylic acids (PFCAs; i.e., PFOA) and/or perfluorinated sulfonic acids (PFSAs; i.e., PFOS), as they degrade in the environment.

Over the past two decades, ubiquitous environmental detections of PFAS have been documented by studies worldwide. Since 2004, the RMP has detected PFAS across matrices in San Francisco Bay with a series of monitoring projects on harbor seals, cormorants, fish, bivalves, sediment, and surface water. A recent 2021 study of PFAS in Bay surface water found 11 PFAS (of 40 analyzed) across 22 sites (Mendez et al., 2022). The sums of detected PFAS for all sites had median and maximum levels of 10 and 29 ng/L, respectively. South and Lower South Bay sites, strongly influenced by wastewater and stormwater due in large part to long residence times, exhibited statistically significant greater sums of PFAS when compared to the rest of the Bay. Sediment has not been measured as consistently as other matrices within the Bay, with the most recent study in 2014 finding various PFAS present (Sedlak et al., 2018). PFOS was detected most frequently and in the highest concentrations.

However, most of these studies have focused on targeted methods analyzing up to 40 individual PFAS. In contrast, a recent regional study of influent, effluent, and biosolids on behalf of the Bay Area Clean Water Agencies (BACWA) detected various PFAS across each matrix using targeted analysis of PFAS, as well as the Total Oxidizable Precursor (TOP) assay to indirectly measure unknown perfluoroalkyl acid precursors (Mendez et al., 2021). The TOP assay permits an assessment of the overall levels of persistent PFCAs and PFSAs that will form in a matrix following transformation of precursors to terminal products; this information is essential for evaluating the broader exposure and risks to Bay wildlife from PFAS. In the BACWA study, influent and biosolids samples examined using the TOP assay indicated the sum of PFAS concentrations roughly doubled compared to sums of only targeted analytes. These findings suggest that there are significant amounts of unidentified precursors in wastewater and likely other matrices. A second phase of the wastewater study will examine target and TOP results from sewershed sites representing residential neighborhoods and specific industries, as well as in influent, effluent, and biosolids.

Additionally, an ongoing study of PFAS in archived sediment samples is also using updated targeted analysis and the TOP assay to more thoroughly assess levels in the Bay. Analyzing samples from RMP margins sediment cruises in 2017 and 2020, this study will provide robust baseline data that can be used to evaluate changes with time.

The use of the TOP assay is a step towards understanding the broader range of PFAS that are present in the environment. Though more comprehensive methods of detecting PFAS beyond those observed via the TOP assay exist or are in development, these methods are significantly less sensitive (much higher detection limits). An initial screening of wastewater samples using one of these methods (AOF; adsorbable organic fluorine) that is underway will provide information to indicate its potential utility in Bay water sampling.

To better understand the occurrence, fate, and potential risks to ecological and human health posed by PFAS, we propose a study to apply the TOP assay to Bay water and sediment samples. These results can be compared to the RMP S&T 2023 and 2024 dry and wet season monitoring of PFAS in Bay water using targeted methods, as well as near-field and margins monitoring of sediment. The results will characterize the occurrence and potential risks posed by a broader sum of PFAS in the Bay. The findings will also inform the State Water Board's statewide investigation of PFAS.

Study Objectives and Applicable RMP Management Questions

The purpose of this study is to assess the concentrations of PFAS and precursors in Bay waters to improve our understanding of risks to wildlife and people. Comparisons to concentrations measured in previous years along with synonymous monitoring of surface water and sediment using targeted analysis will provide a greater understanding of the presence, transport, and fate of PFAS in the Bay. Additionally, we will compare levels of PFAS in different embayments, and across matrices, to monitor potential spatial patterns of contamination. This new study will expand on the limited targeted analysis of 40 analytes to indirectly evaluate the presence PFAS precursors.

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

Management Question	Study Objective	Example Information Application
1) Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay?	Monitor PFAS precursors in Bay water and sediment relative to target PFAS. Compare concentrations of PFAS precursors and aquatic toxicity thresholds, where available.	Are PFAS precursors present in the Bay at concentrations above detection limits? Do PFAS precursors in the Bay have the potential to contribute to PFAS impacts to aquatic life?
2) What are the sources, pathways and loadings leading to the presence of individual CECs or groups of CECs in the Bay?	Compare current precursor concentrations to those previously detected in stormwater and wastewater.	Are there any particular trends from pathways to Bay water and sediment?
3) What are the physical, chemical, and biological processes that may affect the transport and fate of individual CECs or groups of CECs in the Bay?	Compare levels and proportions relative to target PFAS across subembayments.	Do specific subembayments or regions appear to have greater levels of contamination?
4) Have the concentrations of individual CECs or groups of CECs increased or decreased in the Bay?	Comparison to other studies of PFAS in Bay water and sediment	Establish baseline of PFAS precursors in Bay water and sediment
5) Are the concentrations of individual CECs or groups of CECs predicted to increase or decrease in the future?	N/A	N/A
6) What are the effects of management actions?	N/A	N/A

Approach

To accomplish the dry season Bay water and sediment sample collection, additions to the 2023 water and sediment cruise Sampling and Analysis Plans would need to be completed before the Steering Committee makes funding decisions for special studies (August 10th meeting). The Technical Review Committee can provide preliminary guidance on the relative importance of this effort at a meeting on June 20th, which can provide an indication as to whether to move forward pending funding.

<u>Bay Water Sampling</u>

Collection of ambient water samples will be coordinated with the recently updated RMP S&T dry season water monitoring cruise in the summer of 2023 and/or wet season monitoring activities in the winter of 2023-24. All samples will be grab samples of ambient Bay water (125 mL, HDPE), consistent with previous efforts.

During the dry season water cruise, 22 sites will be sampled, a combination of 6 fixed stations and 16 random stations across all five Bay segments, along with a field duplicate and two field blanks. Wet season sampling consists of 13 overall samples, with 7 at near-field sites and 6 at deep Bay stations. The near-field sites include 3 in-Bay stations near stormwater inputs (two storm events) plus one station near wastewater input (only one storm). Four deep Bay sites will be sampled within three weeks of one of the same storms sampled at the near-field locations, including a duplicate and field blank. Overall, 38 samples will be collected and shipped overnight to SGS AXYS, where they will be frozen to extend hold time to 90 days.

Sediment Sampling

Collection of near-field and margins sediment samples will be coordinated with the recently updated RMP S&T sediment monitoring cruise in the summer of 2023. The top 5 cm of sample will be collected using a 0.1 m^2 modified Van Veen sediment grab. In areas where sampling from the boat is not possible, overland access to the site and direct scooping from the target depth of surface sediment may be used.

A total of 20 sites will be sampled for this study during the sediment cruise including 12 margins sites and 8 near-field sites along with a field duplicate and field blank. These sites will be targeted to include areas in the Lower South Bay, where PFAS have been shown to be in greater concentrations in previous studies, as well as any areas not covered in the archived sediment study. Overall, 22 samples will be collected and shipped overnight to SGS AXYS, where they will be frozen to extend hold time to a year.

Analytical Methods

Samples will be analyzed by SGS AXYS (Sidney, BC, Canada) using SGS AXYS method MLA-111 to quantify 40 known PFAS, including breakdown products of various unknown precursors, using the TOP assay (Table 2). Both aqueous and solid samples are spiked with isotopically labeled surrogate standards before oxidation. Following this step, solids are extracted with methanolic ammonium hydroxide and treated with carbon. Aqueous and solid extracts are then oxidized using base and heat activated persulfate. Once cooled and pH-adjusted, the reaction mixture is spiked with isotope labeled quantification standards, extracted, and cleaned up using manual vacuum manifold or automated PromoChrom weak anion exchange SPE. Sample extracts are analyzed by ultrahigh performance liquid chromatography coupled to a triple quadrupole mass spectrometer (UPLC-MS/MS). Final sample concentrations are determined by isotope dilution/internal standard quantification. Reporting limits vary across noted PFAS groups (Table 2).

Table 2. PFAS Analytes in MLA-111 (SGS AXYS)

PFAS Classification/ *Analyte Type*	**PFAS Abbreviation**	**PFAS Name (Conjugate Base in parentheses)**	**Aqueous RLs (ng/L)**	**Solid RLs (ng/g)**
Perfluoroalkyl Carboxylates (PFCAs)/ *Product and non-reacting target*	PFBA	Perfluorobutanoic acid (Perfluorobutanoate)	13	0.8
	PFPeA	Perfluoropentanoic acid (Perfluoropentanoate)	7	0.4
	PFHxA	Perfluorohexanoic acid (Perfluorohexanoate)	3	0.2
	PFHpA	Perfluoroheptanoic acid (Perfluoroheptanoate)		
	PFOA	Perfluorooctanoic acid (Perfluorooctanoate)		
	PFNA	Perfluorononanoic acid (Perfluorononanoate)		
	PFDA	Perfluorodecanoic acid (Perfluorodecanoate)		
	PFUnA	Perfluoroundecanoic acid (Perfluoroundecanoate)		
	PFDoA	Perfluorododecanoic acid (Perfluorododecanoate)		
	PFTrDA	Perfluorotridecanoic acid (Perfluorotridecanoate)		
	PFTeDA	Perfluorotetradecanoic acid (Perfluorotetradecanoate)		
Perfluoroalkyl Sulfonates (PFSAs)/ *Non-reacting target*	PFBS	Perfluorobutanesulfonic acid (Perfluorobutanesulfonate)	3	0.2
	PFPeS	Perfluoropentanesulfonic acid (Perfluoropentanesulfonate)		
	PFHxS	Perfluorohexanesulfonic acid (Perfluorohexanesulfonate)		
	PFHpS	Perfluoroheptanesulfonic acid (Perfluoroheptanesulfonate)		
	PFOS	Perfluorooctanesulfonic acid (Perfluorooctanesulfonate)		
	PFNS	Perfluorononanesulfonic acid (Perfluorononanesulfonate)		
	PFDS	Perfluorodecanesulfonic acid (Perfluorodecanesulfonate)		
	PFDoS	Perfluorododecanesulfonic acid (Perfluorododecanesulfonate)		
Fluorotelomer Sulfonates/ *Reacting precursors*	4:2 FTS	1H, 1H, 2H, 2H-perfluorohexane sulfonic acid (1H, 1H, 2H, 2H-perfluorohexane sulfonate)	13	0.8
	6:2 FTS	1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (1H, 1H, 2H, 2H-perfluorooctane sulfonate)		
	8:2 FTS	1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (1H, 1H, 2H, 2H-perfluorodecane sulfonate)		

PFAS Classification/ *Analyte Type*	**PFAS Abbreviation**	**PFAS Name (Conjugate Base in parentheses)**	**Aqueous RLs (ng/L)**	**Solid RLs (ng/g)**
Fluorotelomer Carboxylates/ *Reacting precursors*	3:3 FTCA	2H, 2H, 3H, 3H-perfluorohexanoic acid (2H, 2H, 3H, 3H-perfluorohexanoate)	13	0.8
	5:3 FTCA	2H, 2H, 3H, 3H-perfluorooctanoic acid (2H, 2H, 3H, 3H-perfluorooctanoate)	83	5
	7:3 FTCA	2H, 2H, 3H, 3H-perfluorodecanoic acid (7:3 FTCA, 2H, 2H, 3H, 3H-perfluorodecanoate)		
Perfluorooctane Sulfonamides/ *Reacting precursors*	PFOSA	Perfluorooctanesulfonamide	3	0.2
	N-MeFOSA	N-Methylperfluorooctanesulfonamide		
	N-EtFOSA	N-Ethylperfluorooctanesulfonamide		
Perfluorooctane Sulfonamido-acetic Acids/ *Reacting precursors*	N-MeFOSAA	N-Methylperfluoro-1-octanesulfonamidoacetic acid (N-Methylperfluoro-1-octanesulfonamidoacetate)	3	0.2
	N-EtFOSAA	N-Ethylperfluoro-1-octanesulfonamidoacetic acid (N-Ethylperfluoro-1-octanesulfonamidoacetate)		
Perfluorooctane Sulfonamido Ethanols/ *Reacting precursors*	N-MeFOSE	N-Methylperfluoro-1-octanesulfonamidoethanol	33	2
	N-EtFOSE	N-Ethylperfluoro-1-octanesulfonamidoethanol		
Per- and Polyfluoroether Carboxylates/ *Varies (2nd and 4th on list are unstable)*	HFPO-DA (GenX)	2,3,3,3-Tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy)propionic acid	13	0.8
	ADONA	Decafluoro-3H-4,8-dioxanonoic acid (Decafluoro-3H-4,8-dioxanonoate)		
	NFDHA	Perfluoro-3,6-dioxaheptanoic acid (Perfluoro-3,6-dioxaheptanoate)	7	0.4
	PFMBA	Perfluoro-4-methoxybutanoic acid (Perfluoro-4-methoxybutanoate)		
	PFMPA	Perfluoro-3-methoxypropanoic acid (Perfluoro-3-methoxypropanoate)	13	0.8
Perfluoroalkyl-ether Sulfonates/ *Varies (First two on list are unstable and may not oxidize completely)*	9Cl-PF3ONS	9-chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9-chlorohexadecafluoro-3-oxanonane-1-sulfonate)	13	0.8
	11Cl-PF3OUdS	11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11-chloroeicosafluoro-3-oxaundecane-1-sulfonate)		
	PFEESA	Perfluoro(2-ethoxyethane)sulfonic acid (Perfluoro(2-ethoxyethane)sulfonate)	3	0.2

Budget

Table 2. Proposed Budgets

Expense	Estimated Hours (Range)	Dry & Wet Seasons (Water & Sediment)	Dry & Wet Seasons (Water Only)	Wet Season Request (Water Only)
Labor				
Study Design	15-45	$6,300	$4,200	$2,100
Sample Collection	20-65	$9,100	$6,300	$2,800
Data Technical Services		$17,000	$12,200	$5,200
Analysis and Reporting	55-185	$25,900	$18,200	$7,700
Subcontracts				
SGS AXYS		$31,400	$19,900	$6,800
Direct Costs				
Travel		$2,000	$1,400	$600
Shipping		$6,000	$5,000	$2,000
Grand Total		**$97,700**	**$67,200**	**$27,200**

Alternatives

Pilot monitoring of targeted PFAS in Bay water and sediment as well as ongoing studies of precursors in wastewater and archived sediment provide an excellent opportunity for a holistic review of a greater breadth of PFAS. Dry season monitoring cruises (water and sediment) are planned to occur this summer, requiring a quick turnaround of study design and inclusion in current sampling and analysis plans for the noted cruises. This study could also occur over several years, with wet season sampling serving as a pilot for the TOP assay in Bay water. The following year would include dry season monitoring of water and sediment, which could be limited to sites of interest based on past data.

<u>Budget Justification</u>

SFEI Labor
Labor hours are estimated for SFEI staff to manage the project, develop the study design, support sample collection, analyze data, briefly review toxicological risks, present findings, and write a report including recommendations on future related monitoring.

Data analysis can include examination of any trends related to chain length (particularly, short vs. long-chain PFAS precursors), spatial trends, and investigation into the influence of different pathways based on a comparison to TOP data from studies in wastewater and stormwater. Costs for sample collection are minimized through leveraging of sampling during the RMP S&T 2023 dry and wet season water cruises as well as the near-field and margins sediment cruises.

Data and Technical Services
Standard RMP data management procedures will be used for this project. Data will not be uploaded to CEDEN.

Laboratory Costs (SGS AXYS)
Analytical costs per sample are estimated at $522 (including additional data package and disposal fees). For 22 samples from dry season monitoring, with a duplicate and two field blanks, the total analytical cost is ~$13,100. Additional analysis of 13 wet season samples, with a duplicate and field blank, is ~$6,800. For analysis of 22 sediment samples, including a duplicate and field blank, is ~$11,500. For all analyses, the total is $31,400. This study leverages target PFAS results covered by S&T monitoring for both Bay water and sediment.

Early Funds Release Request
We request early release of funds for use in 2023 to coordinate with dry and/or wet season S&T monitoring activities.

Reporting

Preliminary results of dry season sampling will be presented to the ECWG at the spring 2024 meeting. A draft report will be prepared by 11/30/24, which will incorporate data from both sampling efforts and be reviewed by the ECWG and TRC. Comments will be incorporated into the final report, published by 02/28/25.

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Special Study Proposal: Non-targeted Analysis of San Francisco Bay Fish

Summary: Contaminants in sport fish may have both human health and ecological implications. The RMP has been monitoring selected contaminants in sport fish for many years but has never done any non-targeted analysis of this matrix. This two-year study would leverage 2024 Status and Trends sport fish monitoring to collect sport fish samples for non-targeted analysis. This type of analysis will provide a means to identify unanticipated contaminants that may merit follow-up targeted monitoring and compare San Francisco Bay fish contaminant profiles with those of fish from other locations such as the Great Lakes. Anticipated study outcomes would include priorities and recommendations for future investigations of newly identified CECs of potential concern observed in sport fish.

Estimated Cost:	$85,000 for two-year study ($23,000 for Year 1)
Oversight Group:	ECWG
Proposed by:	Ezra Miller & Rebecca Sutton (SFEI), Bernard Crimmins (AEACS, Clarkson University)
Time Sensitive:	Yes, leverages S&T sport fish monitoring (2024)

PROPOSED DELIVERABLES AND TIMELINE

Deliverable	Due Date
Task 1. Work with S&T Sport Fish Strategy Team to develop sampling plan	January 2024
Task 2. Sample collection	Summer 2024
Task 3. Lab and data analysis	Fall 2024 - Spring 2026
Task 4. Presentation to ECWG and TRC	April 2026
Task 5. Draft manuscript	June 2026
Task 6. Final manuscript	September 2026

Background

Sport fish in San Francisco Bay are an important matrix in which to understand the contaminant profile, as they are consumed by both people, particularly in low-income and immigrant communities practicing subsistence fishing, as well as by apex predators like cormorants and harbor seals. The RMP began sport fish monitoring in 1997, and Status and Trends samples are collected every five years (most recently in 2019) during the summer season. Data collected through this monitoring program not only provide updates on the status and long-term trends of contaminants in Bay sport fish, but are also used to update human health consumption advisories and evaluate the effectiveness of regulatory and management efforts to reduce the impacts of contaminants of concern in the Bay (Buzby et al. 2019).

Status and Trends sport fish contaminant monitoring by the RMP is focused on a limited list of contaminants: mercury, polychlorinated biphenyls (PCBs), dioxins, selenium, polybrominated diphenyl ethers (PBDEs), and select per- and polyfluoroalkylated substances (PFAS). However, investigations of sport fish and other wildlife collected from other highly urbanized coastal sites indicate that these regularly monitored contaminants represent only a small fraction of the total number of bioaccumulative contaminants present in aquatic life. While the RMP has been monitoring sport fish for many years, to date there has never been any non-targeted analysis of Bay sport fish.

Non-targeted analysis, a key element of the RMP's CEC strategy, can help to provide a measure of assurance that the RMP is not missing unexpected yet potentially harmful contaminants simply because of failures to predict their occurrence based on use or exposure prioritization criteria. This type of non-targeted study can lay the foundation for future targeted CECs monitoring by helping to identify new potential contaminants of concern without *a priori* knowledge of their occurrence. The RMP has conducted successful non-targeted analysis of nonpolar, fat-soluble compounds in bivalve tissue and seal blubber (Sutton and Kucklick 2015), and polar, more water-soluble compounds in Bay water and wastewater effluent (Sun et al. 2020; Overdahl et al. 2021), as well as in fire-impacted stormwater (Miller et al. 2021). Non-targeted analysis of marine mammal tissues is also currently underway as part of a pilot study to inform the RMP's Status and Trends program design.

The proposed study will employ a non-targeted analytical approach to examine samples of Bay sport fish to assess the contaminant profiles in the food chain and identify potential additional contaminants for future monitoring.

Results may indicate the presence of contaminants accumulating in Bay food chains that are not typically analyzed in targeted monitoring studies. Alternatively, should results reveal that most compounds of concern for wildlife and human health are already included in targeted monitoring, this study will help confirm that current Bay monitoring sufficiently captures priority contaminants.

Study Objectives and Applicable RMP Management Questions

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

Management Question	Study Objective	Example Information Application
1) Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay?	Screen CECs identified via non-targeted analysis for potential toxicity concerns, future monitoring needs, and data gaps.	Do any newly identified CECs merit follow-up targeted monitoring?
2) What are the sources, pathways and loadings leading to the presence of individual CECs or groups of CECs in the Bay?	Evaluate chemical profiles for evidence of source types.	Do variations in site profiles suggest influence of any specific sources?
3) What are the physical, chemical, and biological processes that may affect the transport and fate of individual CECs or groups of CECs in the Bay?	Assess results of non-targeted analysis for the presence of unanticipated transformation products.	Do the results of non-targeted analysis indicate transformation of parent compounds into unanticipated contaminants with potential concerns for Bay wildlife or human health?
4) Have the concentrations of individual CECs or groups of CECs increased or decreased in the Bay?	N/A	N/A
5) Are the concentrations of individual CECs or groups of CECs predicted to increase or decrease in the future?	N/A	N/A
6) What are the effects of management actions?	N/A	N/A

Approach

Bay Fish Sampling

Although the RMP Status and Trends (S&T) biota monitoring design was updated in 2022, the design for sport fish remains largely the same, with samples collected every five years. This project will involve collection of additional fish samples in conjunction with the planned 2024 S&T sport fish monitoring, using an "opportunistic" sampling approach planned with the help of the sport fish S&T team as they develop their sampling and analysis plan this fall (fall 2023). Approximately 12 samples will be targeted, more if S&T budget allows.

Core RMP sport fish species include white croaker, shiner surfperch, white sturgeon, striped bass, halibut, northern anchovy, and jacksmelt. Other species are targeted primarily based on information needed to update Bay fish advisories. Species that have been sampled include Pacific herring, Pacific sardine, staghorn sculpin, brown rockfish, blue rockfish, barred surfperch, bat ray, rubberlip perch, black perch, cabezon, Pacific sanddab, diamond turbot, petrale sole, starry flounder, and monkeyface prickleback. Largemouth bass and common carp, which are only found in freshwater in the extreme Lower South Bay, have also been sampled near the San Jose wastewater outfall to track CECs and mercury.

The five existing core S&T stations that have always been sampled as part of S&T monitoring will continue to be monitored, including San Pablo Bay, Berkeley, Oakland, San Francisco Waterfront, and South Bay (may include Redwood Creek, Artesian Slough, and/or Coyote Creek) (Figure 1 green dots). This project would likely sample both expected relatively less contaminated sites such as San Pablo Bay and Berkeley, as well as sites with expected higher contaminant loads such as San Leandro Bay and the South Bay. Shiner surfperch are a good species for spatial comparisons, as they will also be collected from the Priority Margin Unit locations to track PCB trends (Figure 1 orange dots).

Fish are collected using a variety of techniques, including gill nets, otter trawls, and hook and line depending on location and species sought. For most analytes, multiple fish are used to make composite samples. Mercury and selenium in white sturgeon and mercury in striped bass, however, are analyzed in tissue from individual fish, so this project could also potentially take that approach depending on the target species.

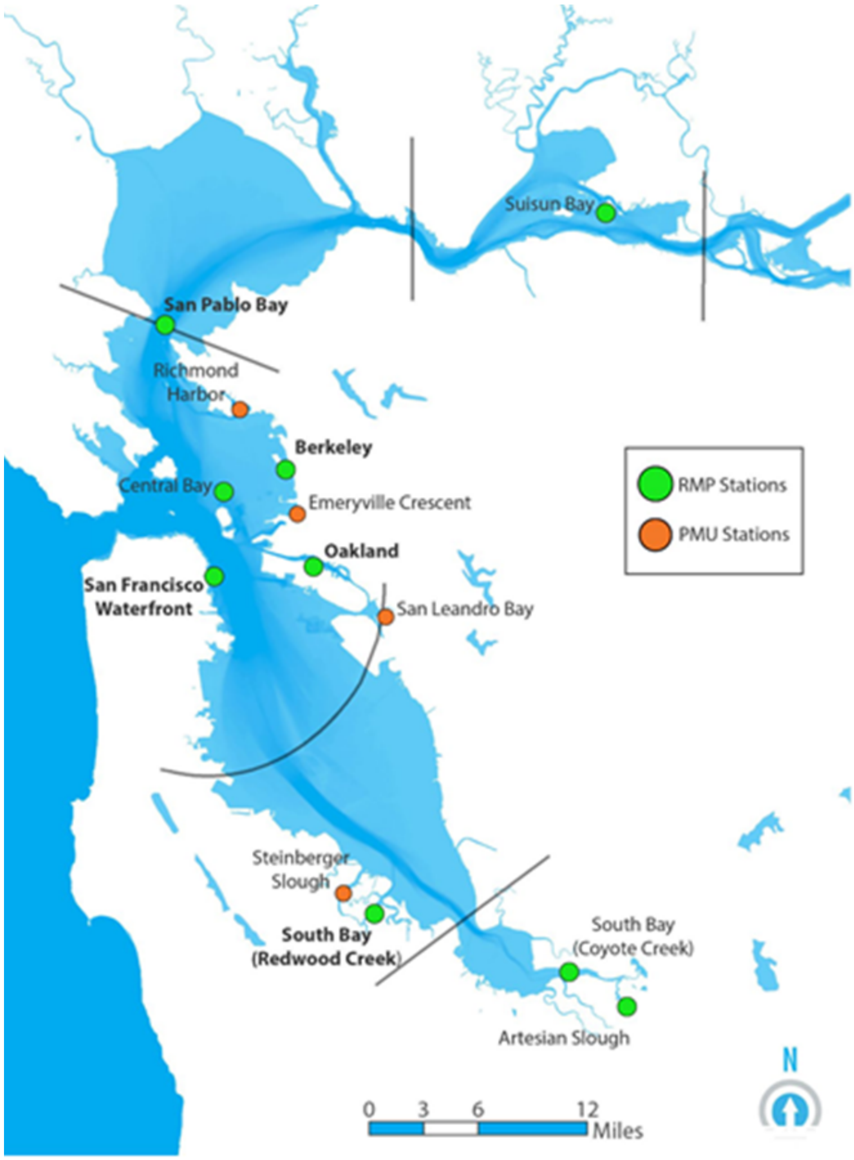

Figure 1. RMP S&T sport fish sampling locations. The green circles with bold names represent the five core stations included in the S&T Program (South Bay includes three locations – Redwood Creek, Artesian Slough, and Coyote Creek). Shiner surfperch will be collected from the Priority Margin Unit locations to track PCB trends (orange circles).

<u>Analytical Methods</u>

Most fish will be dissected skin-off, and only the fillet muscle tissue will be used for analysis. Species that are too small to be filleted (e.g., shiner surfperch, jacksmelt, northern anchovy) will be processed whole but with head, tail, and viscera removed.

For non-targeted screening (Crimmins lab; AEACS, Clarkson University), fish tissue samples will be processed and analyzed using two non-targeted methods: one to look for non-polar compounds, and another to look for polar compounds, especially fluorinated polar compounds such as PFAS. In addition to non-target analyses, ancillary data such as % lipid will be collected.

For non-polar compounds, DCM will be eluted through desiccated fish tissue homogenates followed by size exclusion chromatography for lipid removal (Fernando et al., 2018). Extracts will then be analyzed using a 2-dimensional gas chromatography equipped with a high-resolution time of flight mass spectrometer (GC×GC-HRT, LECO) in accordance with Fernando et al. (2018) and Renaguli et al. (2020). The GC×GC resolves the extract mixture into 1000's of individual components. The exact mass spectra of these components will be compared against a reference library containing over 500,000 chemicals to identify components in the tissues. Previously, this analysis has only been performed using electron impact ionization. The new system also has electron capture negative chemical ionization capabilities (ECNI). This mode selects for compounds that generate negative ions (halogenated components) and is traditionally used by low resolution instruments to quantify legacy halogenated chemicals (e.g., polybrominated diphenyl ethers). The new system is one of few available in the world that provides enhanced sensitivity of ECNI and 2-D chromatographic (GC×GC) and exact mass (30,000) resolution. The result will be a list of halogenated species for each tissue and concentration estimates using one or more representative reference standards. Compound identifications will be qualified by retention time, library matching, and spectral interpretation with exact mass accuracy (< 5 ppm).

Polar compound non-targeted analysis will be performed in accordance with Crimmins et al. (2014) and Fakouri Baygi et al. (2021). Tissue homogenates will be extracted using methods described in Point et al. (2019) and then analyzed by ultra-high performance liquid chromatography-quadrupole time-of-flight mass spectrometry (UPLC-QToF) in electrospray ionization (ESI) mode. The instrument will be configured to operate in a data-independent MS/MS mode, alternating between low and high-energy channels to capture precursor and product ions for identification and confirmation of detected species. The data files will be analyzed using an algorithm developed in-house to screen for halogenated acids including polyfluorinated acids (Fakouri Baygi et al., 2016; Fakouri Baygi et al., 2021). The data reduction will consist of isolating species containing halogenated acid, ether, and sulfonate moieties.

The contaminant profiles for San Francisco Bay sport fish will be compared to profiles acquired previously from Great Lakes sport fish using the same sample preparation and analytical methods.

Budget

Table 2. Budget

Expense	Estimated Hours	Estimated Total Cost	Year 1 Request
Labor			
Study Design and Coordination	60	10,000	8,000
Data Technical Services		0	0
Analysis and Reporting	120	20,000	0
Subcontracts			
AEACS, LLC		50,000	10,000
Direct Costs			
Equipment		2,000	2,000
Shipping		3,000	3,000
Grand Total		**85,000**	**23,000**

Budget Justification

This proposal describes a two-year study with a total budget of $85,000 (split between the two years). Year one will be primarily focused on study design and sample collection.

SFEI Labor
Labor hours are estimated for SFEI staff to manage the project, develop the study design in collaboration with partners, support sample collection, analyze data, review toxicological risks, present findings, and assist with manuscript development.

Data Technical Services
Standard RMP data management procedures have not been developed for non-targeted data. These data will not be uploaded to CEDEN.

Sample Collection

The estimated cost for collecting extra fish samples during the S&T collection efforts is $25,000. Each fish sample cost is estimated at $2,000 - $3,000 per sample (2019 costs were $1,873 for the usual species and $2,810 for hard-to-sample species). The budget of $25,000 therefore covers up to 12 samples, depending on species. These costs are not included in this project budget because they will be funded through S&T; these extra fish samples will be archived if this study is not funded for 2024.

Laboratory Costs

The Crimmins Laboratory (AEACS, Clarkson University) can provide non-targeted analysis using two different methods on up to 12 fish tissues for a total cost of $50,000 (including 25% indirect rate). This budget includes both analysis and manuscript preparation. The majority of the analysis and reporting would take place during year 2 of the study.

Reporting

Results will be presented to the ECWG at the spring 2025 meeting, and may also be presented at a TRC meeting; a draft manuscript led by the Crimmins lab will serve as the RMP technical report for this project (draft for RMP review due September 2025, submission-ready draft[1] due December 2025).

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Special Study Proposal: PFAS and Nontargeted Analysis of Marine Mammal Tissues Year 2

Summary: A recent review of the RMP Status and Trends (S&T) Monitoring Program design led to the recommendation to explore the addition of Bay marine mammals, such as harbor seals, to the species included in periodic S&T monitoring. To inform the potential inclusion of marine mammals to the long-term S&T program, this two-year study includes examination of PFAS in multiple tissues of two local species, harbor seals and harbor porpoises. This proposal adds nontargeted analysis of PFAS and hydrophobic halogenated compounds to the pilot study, providing a means to identify unanticipated contaminants that may merit follow-up targeted monitoring. Study outcomes would include recommendations for S&T monitoring of marine mammals, as well as priorities for future investigations of newly-identified CECs observed in marine mammal tissues. This proposal is for the second year of this two-year project.

Estimated Cost:	$126,500 for Year 2 (Year 1 was $115,500, funded via S&T)
Oversight Group:	ECWG
Proposed by:	Ezra Miller and Rebecca Sutton (SFEI), Bernard Crimmins (AEACS, Clarkson University), Eunha Hoh (San Diego State University)
Time Sensitive:	Yes (multi-year study already underway)

PROPOSED DELIVERABLES AND TIMELINE

Deliverable	Due Date
Task 1. Update sampling plan as necessary	January 2024
Task 2. Sample collection	2023-2024
Task 3. Target PFAS analysis	2023-2024
Task 4. Nontargeted analysis	2023-2024
Task 5. Draft manuscript(s), S&T study design recommendations (technical memo), presentation to TRC	June 2025
Task 6. Final manuscript(s)	September 2025

Background

Through special studies, the RMP has conducted periodic monitoring of CECs in Pacific harbor seals (*Phoca vitulina richardii*) in San Francisco Bay. These apex predators have relatively high site fidelity, such that contaminants observed in their tissues are likely derived from the local food web. Previous RMP investigations (Sedlak et al., 2007; Sedlak et al., 2017; Sedlak et al., 2018) have indicated that harbor seals in the South Bay are exposed to high levels of per- and polyfluorinated alkyl substances (PFAS), a broad class of fluorine-rich contaminants that are of elevated environmental concern because they are ubiquitous, extremely persistent, and several have been shown to be highly toxic and bioaccumulative. Temporal trends in harbor seal serum concentrations suggest declines in perfluorooctane sulfonate (PFOS) following its phase-out in the US; however, perfluorooctanoic acid (PFOA) and other long-chain carboxylates have not shown similar declines (Sedlak et al., 2017).

To explore whether it would be appropriate to add marine mammals to the S&T study design for PFAS monitoring, the RMP is piloting monitoring of marine mammal tissues, leveraging existing recovery and sample collection efforts by the Marine Mammal Center (Sausalito, CA) of two resident Bay species, Pacific harbor seals and harbor porpoises (*Phocoena phocoena*).

Two tissues, serum and liver, are being monitored for PFAS. Improved targeted analytical techniques will allow quantification of many more fluorinated compounds than previously available. Liver samples will also be examined for additional PFAS via nontargeted analysis; recent studies of marine mammal tissues have used nontargeted analysis to identify additional PFAS and other halogenated compounds and classes that have not been observed previously in marine mammals (e.g., Liu et al., 2018; Spaan et al., 2019).

In addition to PFAS, marine mammals tend to bioaccumulate hydrophobic and persistent chlorinated and brominated organic contaminants. The RMP funded a nontargeted analysis of Bay seal blubber samples a decade ago, which identified chlorinated and brominated compounds including legacy pollutants and their metabolites and a few additional contaminants that had not been previously monitored (Sutton and Kucklick, 2015). Methods have improved significantly in recent years; an examination of additional blubber samples using improved methods is expected to reveal new insights. A recent nontargeted analysis of southern California marine mammal blubber samples observed almost 200 halogenated organic contaminants, 81% of which are not routinely monitored by traditional targeted methods (Cossaboon et al., 2019).

To build on previous RMP marine mammal tissue monitoring and to more fully understand the occurrence of contaminants in top Bay predators, we propose a continuation of the current study leveraging the Marine Mammal Center sample collection efforts to evaluate concentrations of nontarget PFAS and identify nontarget nonpolar contaminants in harbor seal and harbor porpoise tissues.

Results may indicate the presence of PFAS and other contaminants accumulating in Bay wildlife that are not typically analyzed in targeted monitoring studies. Alternatively, this study may help confirm that current Bay monitoring sufficiently captures priority contaminants.

Study Objectives and Applicable RMP Management Questions

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

Management Question	Study Objective	Example Information Application
1) Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay?	Evaluate target PFAS concentrations relative to tissue-specific ecotoxicity studies. Screen CECs identified via nontargeted analysis for potential toxicity concerns.	Are PFAS concentrations at or above levels associated with health impacts in mammals? Do any newly identified CECs merit follow-up targeted monitoring?
2) What are the sources, pathways and loadings leading to the presence of individual CECs or groups of CECs in the Bay?	Evaluate chemical profiles for evidence of source types.	Do PFAS profiles suggest influence of any specific sources?
3) What are the physical, chemical, and biological processes that may affect the transport and fate of individual CECs or groups of CECs in the Bay?	Assess results of nontargeted analysis for the presence of unanticipated transformation products.	Do the results of nontargeted analysis indicate transformation of parent compounds into unanticipated contaminants with potential concerns for Bay wildlife?
4) Have the concentrations of individual CECs or groups of CECs increased or decreased in the Bay?	Compare target PFAS concentrations in harbor seal serum to prior observations.	Do concentrations in harbor seal serum suggest temporal trends for any target PFAS relative to previous years' monitoring?
5) Are the concentrations of individual CECs or groups of CECs predicted to increase or decrease in the future?	N/A	N/A
6) What are the effects of management actions?	N/A	N/A

Approach

Study Design

Tissues from ten harbor seals and ten harbor porpoises will be collected over approximately two years (2023-2024). Animals recovered from within San Francisco Bay will be the highest priority for analysis. However, to reach target sample size, we may also include animals found along the nearby coast (e.g., Half Moon Bay to Point Reyes). Tissues from animals found along the nearby coast will be collected but may not be analyzed, depending on the number of animals recovered from within San Francisco Bay. Tissues from additional animals may be collected and archived if more than ten animals of each species are recovered from within San Francisco Bay.

This study will focus on harbor seal pups. The majority of the live harbor seals that the Marine Mammal Center receives for rehabilitation are pups, which arrive as early as February, with the peak usually in April. Until approximately mid-May, these animals are generally younger than weaning age. The pups will likely be too young to have eaten any prey items from San Francisco Bay, but will have bioaccumulated contaminants from their mother (although how much milk they received before rehabilitation cannot be determined). Previous studies on harbor seals showed higher concentrations of PFOS and perfluorodecanesulfonic acid (PFDS) in tissues of pups than (non-paired) adults, whereas concentrations of perfluorocarboxylic acids like PFOA were similar between pups and adults (Shaw et al., 2009), indicating fluorinated compounds are passed not just via milk but also via placental transfer. Pups that survive rehabilitation can be used for serum monitoring; pups that do not survive rehabilitation are suitable for monitoring multiple tissues, including liver.

Porpoise samples will be obtained from stranded (recently deceased) animals recovered by the Marine Mammal Center all year round, with greatest numbers generally observed in the summer.

Liver samples will be collected for targeted and nontargeted PFAS analysis, serum samples will be collected for targeted PFAS analysis, and blubber samples will be collected for nontargeted analysis of hydrophobic halogenated contaminants. Results will be compared between tissues and species, and harbor seal serum results will be compared to prior RMP data to assess temporal trends. Contaminant profiles will also be compared to southern California pinniped and cetacean data to assess broader geographic trends. Nontargeted PFAS analysis will determine if targeted PFAS analysis captures the majority of PFAS present.

Tissue Sampling

Studies of the tissue distribution of PFAS in harbor seals indicate the highest body burden in blood (38%) and liver (36%), with a relatively low burden (2%) in blubber (Ahrens et al., 2009). Similarly, harbor porpoise livers have the highest levels of PFAS compared with other tissues (Van de Vijver et al., 2007). To our knowledge, no literature exists comparing PFAS in blood serum versus liver in porpoises.

Up to 60 g of liver and 40 g of blubber will each be sampled by the Marine Mammal Center from up to 10 harbor seals and 10 harbor porpoises. These tissues will be subsampled to send to multiple laboratories (see below). Blood samples will be collected from harbor seal pups while still alive, and from stranded (deceased) harbor porpoises; blood sample collection constraints reflect differences in biology and capture/rehabilitation limitations of the two species. Serum will be separated from whole blood by the Marine Mammal Center and used for analysis.

Serum from additional harbor seal pups (up to 10) who survive rehabilitation and were collected from within San Francisco Bay may also be collected and analyzed.

<u>Analytical Methods</u>

PFAS Targeted Analysis

For targeted quantification of PFAS (SGS AXYS; analytes listed in Table 2), liver tissue samples will be spiked with isotopically labeled surrogate standards, then extracted with methanolic potassium hydroxide solution, with acetonitrile, and finally with methanolic potassium hydroxide solution, each time collecting the supernatants. The supernatants are combined, treated with ultra pure carbon powder and evaporated to remove methanol. The resulting solution is diluted with water and cleaned up by solid phase extraction using weak anion exchange cartridges. The extracts will then be spiked with recovery standards, and analyzed by liquid chromatography/mass spectrometry (LC-MS/MS). Serum samples will be spiked with isotopically labeled surrogate standards and then extracted with 50% formic acid. The resulting solution will be cleaned up by solid phase extraction on a weak anion exchange sorbent. The eluent tubes will be spiked with recovery standards and then eluent collected and analyzed by LC-MS/MS.

Analysis of sample extracts will be performed on a UPLC-MS/MS (ultrahigh performance liquid chromatography) reversed phase C18 column using a solvent gradient. The column is coupled to a triple quadrupole mass spectrometer run at unit mass resolution in the Multiple Reaction Monitoring (MRM) mode, using negative electrospray ionization. Final sample concentrations are determined by isotope dilution/internal standard quantification. Each compound is determined as the total of linear and branched isomers where branched standards are available to confirm their retention time.

Table 2. Targeted PFAS analytes.

Perfluoroalkyl carboxylates	Perfluorobutanoic acid (PFBA) Perfluoropentanoic acid (PFPeA) Perfluorohexanoic acid (PFHxA) Perfluoroheptanoic acid (PFHpA) Perfluorooctanoic acid (PFOA) Perfluorononanoic acid (PFNA) Perfluorodecanoic acid (PFDA) Perfluoroundecanoic acid (PFUnA) Perfluorododecanoic acid (PFDoA) Perfluorotridecanoic acid (PFTrDA) Perfluorotetradecanoic acid (PFTeDA)
Perfluoroalkyl sulfonates	Perfluorobutanesulfonic acid (PFBS) Perfluoropentanesulfonic acid (PFPeS) Perfluorohexanesulfonic acid (PFHxS) Perfluoroheptanesulfonic acid (PFHpS) Perfluorooctanesulfonic acid (PFOS) Perfluorononanesulfonic acid (PFNS) Perfluorodecanesulfonic acid (PFDS) Perfluorododecanesulfonic acid (PFDoS)
Fluorotelomer sulfonates	1H, 1H, 2H, 2H-perfluorohexane sulfonic acid (4:2 FTS) 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS) 1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)
Fluorotelomer carboxylates	2H, 2H, 3H, 3H-perfluorohexanoic acid (3:3 FTCA) 2H, 2H, 3H, 3H-perfluorooctanoic acid (5:3 FTCA) 2H, 2H, 3H, 3H-perfluorodecanoic acid (7:3 FTCA)
Perfluorooctane sulfonamides	Perfluorooctanesulfonamide (PFOSA) N-Methylperfluorooctanesulfonamide (N-MeFOSA) N-Ethylperfluorooctanesulfonamide (N-EtFOSA)
Perfluorooctane sulfonamidoacetic acids	N-Methylperfluoro-1-octanesulfonamidoacetic acid (N-MeFOSAA) N-Ethylperfluoro-1-octanesulfonamidoacetic acid (N-EtFOSAA)
Perfluorooctane sulfonamidoethanols	N-Methylperfluoro-1-octanesulfonamidoethanol (N-MeFOSE) N-Ethylperfluoro-1-octanesulfonamidoethanol (N-EtFOSE)
Ether carboxylates	2,3,3,3-Tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy)propionic acid (HFPO-DA) Decafluoro-3H-4,8-dioxanonoate (ADONA, DONA) Perfluoro-3,6-dioxaheptanoate (NFDHA) Perfluoro-3-methoxypropanoate (PFMPA) Perfluoro-4-methoxybutanoate (PFMBA)

Ether sulfonates	9-chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9Cl-PF3ONS) 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS) Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)

Nontargeted Analysis for Fluorinated Compounds

For nontargeted screening for PFAS (Crimmins lab; AEACS, Clarkson University) in liver homogenates, samples will be processed in accordance with Crimmins et al. (2014) and Fakouri Baygi et al. (2021). Homogenates will be extracted using methods described in Point et al. (2019) and then analyzed by ultra-high performance liquid chromatography-quadrupole time-of-flight mass spectrometry (UPLC-QToF) in electrospray ionization (ESI) mode. The instrument will be configured to operate in a data-independent MS/MS mode, alternating between low and high energy channels to capture precursor and product ions for identification and confirmation of detected species. The data files will be analyzed using an algorithm developed in house to screen for halogenated acids including polyfluorinated acids (Fakouri Baygi et al., 2016; Fakouri Baygi et al., 2021). The data reduction will consist of isolating species containing halogenated acid, ether, and sulfonate moieties.

Nontargeted Analysis for Non-Polar Compounds

Nontargeted screening for non-polar compounds will be performed on blubber by two laboratories. Cross-laboratory comparison of contaminant identifications using complementary methods and libraries of spectra will allow for broader determination of the presence of unanticipated, bioaccumulative contaminants in blubber samples. Collaboration between the two labs on the analysis of the blubber samples will help confirm results.

In the Crimmins lab (AEACS, Clarkson University), DCM will be eluted through desiccated blubber homogenates followed by size exclusion chromatography for lipid removal (Fernando et al., 2018). Extracts will then be analyzed using a 2-dimensional gas chromatography equipped with a high-resolution time of flight mass spectrometer (GC×GC-HRT, LECO) in accordance with Fernando et al. (2018) and Renaguli et al. (2020). The GC×GC resolves the extract mixture into 1000's of individual components. The exact mass spectra of these components will be compared against a reference library containing over 500,000 chemicals to identify components in the tissues. Previously, this analysis has only been performed using electron impact ionization. The new system also has electron capture negative chemical ionization capabilities (ECNI). This mode selects for compounds that generate negative ions (halogenated components) and is traditionally used by low resolution instruments to quantify legacy halogenated chemicals (e.g., polybrominated diphenyl ethers). The new system is one of few available in the world that provides enhanced sensitivity of ECNI and 2-D chromatographic (GC×GC) and exact mass (30,000) resolution. The result will be a list of halogenated species for each tissue and concentration estimates using one or more representative reference standards. Compound identifications will be qualified by retention time, library matching, and spectral interpretation with exact mass accuracy (< 5 ppm).

In the Hoh lab (San Diego State University), blubber will be processed following protocols outlined by Cossaboon et al. (2019). Final extracts will be analyzed on a Pegasus 4D GC×GC/TOF-MS equipped with an Agilent 6890 gas chromatograph using instrument parameters optimized for marine mammal blubber by Hoh et al. (2012). Data will be processed using the LECO ChromaTOF mass spectrometer data system (version 4.51.6.0 optimized for Pegasus) and an automated data handling procedure. Briefly, custom data reduction software was developed based on the algorithm described by Pena-Abaurrea et al. (2014), which examined mass spectra for ion intensity ratios characteristic of halogenation. Additional rules and a cross-checking procedure are then applied to reduce the false positive rate. If the same mass spectrum is present in > 2 samples, the cross-checking procedure requires a manual search for the compound in the remaining samples.

The contaminant profiles for San Francisco Bay harbor seals and harbor porpoises will be compared to profiles acquired previously from southern California marine mammal blubber. All analyses were conducted with the same sample preparation and GC×GC/TOF-MS methods. This includes the Shaul et al. (2014) and Mackintosh (2016) datasets consisting of 8 dead stranded common bottlenose dolphin (*Tursiops truncatus*) collected between 1995-2010 and the Cossaboon et al. (2019) dataset consisting of three cetacean species (n = 5 individuals each) and two pinniped species (n = 5 individuals each) that were dead stranded or bycatch, collected between 1990-2014. The cetaceans were long-beaked common dolphin (*Delphinus delphis bairdii*), short-beaked common dolphin (*Delphinus delphis delphis*), and Risso's dolphin (*Grampus griseus*). The pinnipeds were California sea lion (*Zalophus californianus*) and Pacific harbor seal. Results from these three prior studies have been merged into a single dataset containing approximately 400 biomagnifying contaminants identified in the California marine environment.

Table 3. Summary of study design

Species	**Tissue**	**Max # of Samples**	**PFAS Targeted** SGS AXYS	**PFAS Nontargeted** Crimmins lab	**Hydrophobic Nontargeted** Crimmins lab and Hoh lab
Harbor seal	Serum	20	x		
	Liver	10	x	x	
	Blubber	10			x
Harbor porpoise	Serum	10	x		

	Liver	10	x	x	
	Blubber	10			x

Budget

Table 4. Estimated costs (estimated hours are for both years; estimated costs reflect only the second year).

Expense	Estimated Hours (2023-2024)	Estimated Cost (2024 only)
Labor		
Study Design	40	NA[1]
Sample Collection	48	3,000
Data Technical Services		10,000
Analysis and Reporting	180	18,000
Subcontracts		
AEACS, LLC		50,000
San Diego State University		25,000
SGS AXYS		19,000
Direct Costs		
Equipment		NA
Travel		0
Shipping		1,500
Grand Total		**126,500**

Budget Justification

This proposal describes year two of a two-year study with a total budget of $242,000 (year 1 funded for $115,500). Options to significantly reduce the budget include eliminating all or some of the nontargeted analyses. Reducing the number of samples would result in only modest changes to the budget. Increasing the number of samples for targeted analyses would only modestly increase the budget; however, increasing the number of samples for nontargeted analyses would require larger budget increases.

[1] Not applicable because covered by Year 1 funding

SFEI Labor
Labor hours are estimated for SFEI staff to manage the project, develop the study design in collaboration with partners, support sample collection, analyze data, review toxicological risks, present findings, assist with manuscript development, and prepare a technical memo detailing study design recommendations for S&T monitoring.

Data Technical Services
Standard RMP data management procedures will be used for target PFAS data. These data will be uploaded to CEDEN.

Sample Collection
Costs are minimized by leveraging existing marine mammal recovery and sample collection activities of the Marine Mammal Center.

Laboratory Costs
For target PFAS analysis, SGS AXYS analytical costs are $582 per liver sample and $521 per serum sample. The analytical budget of $19,000 includes analysis of blood and liver tissues from 20 specimens, one liver field duplicate for each species, and two standard reference tissues, for a total of 25 samples, plus up to 10 additional serum samples from live harbor seal pups.

The Crimmins Laboratory (AEACS, Clarkson University) will provide nontargeted analysis for PFAS on liver tissues and nonpolar halogenated compounds on blubber tissues for a total cost of $100,000 (including 25% indirect rate). This budget includes both analysis and manuscript preparation.

The Hoh Laboratory (San Diego State University) will provide complementary nontargeted analysis of nonpolar halogenated compounds on blubber tissues for a total cost of $50,000 (including 25% indirect rate). Liver tissues may also be analyzed, if appropriate. This budget includes both analysis and manuscript preparation.

Reporting

Deliverables will include: a) draft manuscript(s) that serve as RMP technical report(s) (draft for RMP review due June 2025, submission-ready draft[2] due September 2025); b) a technical memo describing S&T study design recommendations, due June 2025; and c) a presentation of study design recommendations to the TRC.

[2] The draft manuscript will be distributed to RMP stakeholders for review by email, not published on the website, so as to not interfere with publication in a peer-reviewed journal.

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Special Study Proposal: Pilot Study for Field Collection Methods and Particle Distribution Analysis of Microplastics in Urban Stormwater to San Francisco Bay

Summary: In 2019, the San Francisco Bay Microplastics Project identified urban stormwater runoff as the major pathway for microplastics entering the Bay. More recent investigations on the sources and pathways of microplastics revealed that tire-wear particles and other smaller microplastics were under-counted in previous investigations due to collection and analytical methods. In addition, while depth-integrated sampling was prioritized for the 2019 study to better characterize microplastics in the full water column, this approach requires considerable labor resources relative to stormwater samples collected at a single depth, which is a more likely sampling scenario for any kind of automated sampling program. This proposed field study will take pilot steps to provide a better characterization of microplastics in urban stormwater runoff and inform estimates on the magnitude of loads to the Bay by taking simultaneous single-depth and depth-integrated samples at two field sites during one storm each and comparing the microplastics content of these samples using advanced laboratory techniques that characterize tire wear and other fine particles.

Estimated Cost:	$119,500 (Year 1: $68,100)
Oversight Group:	MPWG
Proposed by:	Diana Lin, Alicia Gilbreath, Kelly Moran, Tan Zi, Lester McKee, Rebecca Sutton (SFEI)
Time Sensitive:	Yes, inform statewide plastics monitoring strategy

PROPOSED DELIVERABLES AND TIMELINE

Deliverable	Due Date
Task 1. Develop conceptual model and refine study design	June 2024
Task 2. Site selection and field reconnaissance	August 2024
Task 3. Sample collection	March 2025
Task 4. Laboratory analysis	September 2025
Task 5. Draft technical report	December 2025
Task 6. Final technical report	February 2025

Background

Through the San Francisco Bay Microplastics Project (Sutton et al., 2019), SFEI researchers identified urban stormwater runoff as the dominant pathway for microplastics entering the Bay. Average microplastic concentrations in urban stormwater runoff were over 100 times greater than average wastewater effluent concentrations. SFEI used a previously developed Regional Watershed Spreadsheet Model (RSWM) to extrapolate measured results and estimated that on the order of 7 trillion microplastic particles were entering the Bay per year, primarily from urban stormwater runoff. Tire-wear particles and fibers were the most abundant types of microplastics in urban stormwater runoff, and combined represented most of the microplastics observed in urban stormwater samples. More recent literature review, synthesis, and analysis (Moran et al., 2021; Moran et al., 2023) funded by the RMP and others has revealed that tire-wear particles and other smaller microplastics were under-counted in previous investigations due to the 125 µm sieve size used during field sampling, as well as the density separation methods used to extract microplastics from the samples.

Another important consideration for field sampling is whether vertical depth integration is critical for measuring stormwater runoff concentrations, or whether water column concentrations are sufficiently well-mixed that sampling at a single depth in the water column is sufficient for answering RMP management questions. During the original Microplastics Project, depth-integrated sampling was conducted at most urban stormwater sites. However, for suspended sediment stormwater sampling, the RMP has found that concentrations in many Bay Area channels are sufficiently well-mixed during storm flow events that it is a reasonable compromise to utilize single-depth sampling in the channel thalweg (deepest portion of channel) when vertical-integrated sampling is logistically not practical. Considering that microplastics are likely to have even slower settling velocities compared to suspended sediment (due to microplastics' lower density and larger surface area), we hypothesize that most microplastics may be sufficiently well-mixed in storm flows in many channels and that single-depth sampling may also be sufficient for microplastics. If single-depth sampling is found to be sufficient for microplastic stormwater sampling, this would open up more opportunities to leverage the RMP's developing urban stormwater monitoring program, including the development of automated remote samplers that would likely be sampling at a single depth during storm events.

Given the importance of the urban stormwater runoff pathway for microplastics, it is important to collect more urban stormwater data in the Bay area to inform and improve upon previous findings. **This study would pilot different urban stormwater microplastic field sample collection approaches to provide recommendations for future urban stormwater monitoring needs. Additionally, this study would provide more comprehensive information about the distribution of microplastics in Bay stormwater runoff by capturing and analyzing microplastics that were under-represented in previous efforts.**

The California Ocean Protection Council (OPC) and State Water Board (SWB) have funded the Southern California Coastal Water Research Project (SCCWRP) to develop standardized field sampling methods for stormwater flows and other matrices that can be used to collect statewide microplastic monitoring data. This proposal provides an important opportunity to coordinate and collaborate to inform key data gaps about the characterization and distribution of microplastics in urban stormwater runoff, as well as their vertical distribution and transport, and to inform appropriate field sampling and analytical methods for monitoring. Coordinating RMP efforts with the OPC/SCCWRP effort will allow for greater context for interpreting urban stormwater runoff sampling results in the Bay Area and southern California and piloting urban stormwater sampling methods that are appropriate for the smaller creeks and rivers in the Bay Area compared to the large concrete river channels in southern California. Recommendations from this study could also inform future statewide monitoring priorities and methods.

Study Objectives and Applicable RMP Management Questions

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

Management Question	Study Objective	Example Information Application
1) What are concentrations of microplastics in the Bay?	*Not applicable*	*Not applicable*
2) What are the health risks?	*Not applicable*	*Not applicable*
3) What are the sources, pathways, loadings, and processes leading to microplastic pollution in the Bay?	- Pilot sampling approaches for microplastics in urban stormwater that are suitable for the Bay Area's watersheds - Measure microplastic concentrations in urban stormwater	-What is the composition of microplastics in urban stormwater runoff ? - What uncertainties and biases are introduced from different sampling approaches? - How do results compare with previous urban stormwater runoff measurements?
4) Have the concentrations of microplastics in the Bay increased or decreased?	*Not applicable*	*Not applicable*
5) Which management actions may be effective in reducing microplastic pollution?	*Not applicable*.	*Not applicable*

Approach

<u>Study design development</u>
First, we will briefly review and synthesize published literature and coordinate with other researchers investigating microplastics in stormwater flows to refine the study design. This includes making sure we are identifying the key gaps that have not been addressed by others and that will be most useful for informing RMP management questions. We will also make sure we are applying best practices and analytical methods for microplastic analysis.

In this pilot study, we will collect an initial set of samples to compare microplastic urban stormwater collection efforts at a single depth in the creek flow compared to vertically-integrated urban stormwater samples that are expected to be representative of water column concentrations. We will select two watershed sampling sites with the following considerations.

- High concentrations of microplastics in stormwater flows are expected based on previous monitoring or land use characteristics.
- Availability of information at the sampling location, including cross-sectional area, predicted depth ranges and flow velocities. Sites with channel size and shape that are representative of other watershed sampling sites in the region are preferred.
- Site analysis suggests well-mixed conditions are likely during typical storm events. This analysis will be informed by flow monitoring and hydraulic analysis, and published sediment transport tools and models adapted for microplastics. For example, Cowger et al., 2021, adapted Rouse profile (non-dimensional number in fluid dynamics used to define concentration profile of suspended sediment) analyses for microplastics by making assumptions of buoyancy and settling velocities, and sampling location characteristics. We can use such tools to derive theoretical mixing status of microplastic particles at different flow conditions for selected sampling sites.

<u>Urban stormwater sample collection</u>

The two selected sites will each be sampled once during a storm event. Microplastic urban stormwater samples will be collected using ISCO pumps, pumped through a stack of sieves similar to previously deployed methods (Sutton et al., 2019) with a few important improvements. Stacked sieves will include 355 µm, 125 µm, 53 µm, and 20 µm sieves. The addition of the smaller sieves allows capture of smaller microplastic size fractions that were not captured previously. These smaller sieves have recently been successfully deployed to collect urban stormwater runoff samples entering bioretention rain gardens in San Francisco. Similar to previous approaches, samples will be collected by taking a series of “sips” during the rising and falling stages of a storm hydrograph to try to collect a representative urban stormwater sample. We will use the ISCO pump to collect samples at different depths as follows for each site (2 sites total) during one storm event (Figure 1).

- 2 depth-integrated samples collected in the channel thalweg
- 2 sets of 3 single-depth samples at varying depths (surface, mid-, near-bottom) in or near the channel thalweg, for a total of 6 single-depth samples

Best practices will be used to avoid sample contamination, including collection of field blanks.

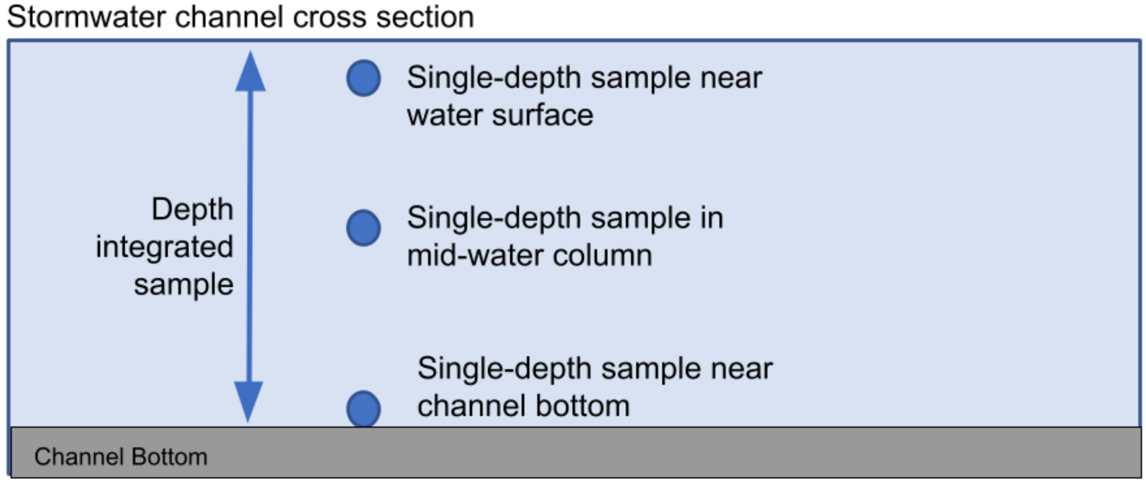

Figure 1: Diagram of proposed sample collection depth in water channel.

Alongside the microplastic sample collection, we will measure turbidity and suspended solids concentration (SSC) in the water column to compare with microplastics levels. Turbidity will be measured in the field using a turbidity meter by collecting small samples into a vial at the same depth as the single-depth microplastic sample collecting (surface, mid-, and near bottom) at different time intervals during the course of the microplastic sample collecting. Measured turbidity during each "sip" will be recorded on field sheets.

SSC measurements will be collected as a composite of the turbidity "sip" samples described above. Collected composite samples will be filtered, dried, and weighed at SFEI (or contracting laboratory), and SSC recorded.

<u>Microplastic analysis</u>

Samples will be processed in a clean lab by gently rinsing material collected on the sieves into a clean glass jar using Milli-Q water.

Microplastics, including tire-wear particles, will be extracted from sediment by density-separation. The mass of microplastics in each sieve, including tire-wear particles, will be weighed. A representative sub-sample from each sieve sample will be characterized for number of particles, morphology, and dimensions (length and width) and polymer using FTIR and/or Raman spectroscopy. A subset of tire-wear particles will be confirmed using SEM-EDS or pyrolysis-GC/MS.

Since the science of microplastic and tire-wear particle analysis is rapidly evolving, literature review and coordination with other researchers will be essential to informing best practices and analytical methods.

<u>Data interpretation</u>
Microplastic concentrations at each depth will be compared with the turbidity and SSC measurements to see if there are correlations among measurements and provide some

information of how microplastics transport compares with SSC. We will compare the measured microplastics concentration profiles with the derived theoretical profiles for the sample events to evaluate if conditions were expected to be well-mixed. We will also compare the levels and composition of microplastics in the samples collected at different depths with the vertically integrated sample. Based on this initial set of results, we will provide a recommendation on whether additional study is advised to answer the question: Can simplified single-depth sampling methods be used to representatively (appropriate for estimating loads) measure microplastics (or a subset of microplastics) samples in urban stormwater runoff during well-mixed flow conditions?

We will also provide recommendations for future urban stormwater monitoring to address RMP microplastic data needs to be outlined by the RMP Microplastics Strategy.

Communication

Results will be summarized in a technical report that will include recommendations for next steps in urban stormwater monitoring. Results will be shared with RMP, SCCWRP, OPC, and SWB to inform future monitoring efforts.

Budget

Table 2. Budget

Expense	Estimated Hours	Estimated Cost	Year 1 Request
Labor			
Study design	164	28,100	28,100
Sample Collection	143	20,800	20,800
Data management	44	7,000	0
Analysis and Reporting	250	31,400	0
Subcontracts			
Laboratory analysis (Ocean Diagnostics or equivalent laboratory)	N/A	26,000	13,000
Direct Costs			
Honoraria - 1 science advisor		2,000	2,000
Equipment, supplies, shipping		4,200	4,200
Grand Total		**119,500**	**68,100**

Budget Justification

Study design
SFEI staff will conduct literature review and coordinate with other researchers investigating microplastics in stormwater to refine the study design and data analysis. Hours are also included for site reconnaissance and data analysis for selected sites to provide a rough estimate of mixing processes based on anticipated flow conditions.

Sample collection
SFEI hours are estimated to staff 2 storm sampling events with three staff members. This includes staff time needed for monitoring and preparing for sampling events. Post sampling processing and analysis of SSC samples by SFEI staff is included.

Data management
Data management services include recording field collection information, communication with the laboratory, and QA review. Data will not be uploaded to a public database.

Analysis and Reporting
SFEI hours are estimated for microplastic data analysis, as well as post-event data analysis to derive microplastic concentration depth profiles for the sampled event and compare to measured concentrations. Project updates will be shared during MPWG meetings. Results and findings will be summarized in a draft and final report.

Subcontracts/Laboratory Costs
Sample analytical costs are estimated to be $1,300/sample for 20 samples (16 field samples + 4 field blanks).

Direct Costs
Direct costs will cover equipment, supplies, and shipping costs.

Reporting

Deliverables will include a draft and final technical report.

References

Cowger, W., Gray, A. B., Guilinger, J. J., Fong, B., & Waldschläger, K. 2021. Concentration Depth Profiles of Microplastic Particles in River Flow and Implications for Surface Sampling. *Environmental Science & Technology*, 55(9), 6032–6041. https://doi.org/10.1021/acs.est.1c01768

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SEP Proposal
Size Distribution of Microplastic Particles in San Francisco Bay

Study Budget, Total: $65,000 - $105,000

SFEI Contacts: Ezra Miller (ezram@sfei.org) and Diana Lin (diana@sfei.org)

Analytical Laboratory Partner: Ocean Diagnostics or other suitable laboratory

Study Description

MPWG Management Question 2 asks, "What are the health risks of microplastics in San Francisco Bay?" Accurate assessment of potential risks from microplastics requires holistic exposure data to compare directly to ecotoxicological thresholds. Although our previous monitoring in San Francisco Bay (Sutton et al., 2019) remains one of the most comprehensive microplastics monitoring data sets, the more reliable surface water data were collected by manta trawl using 355 µm mesh nets, which underestimates the abundance of microplastics smaller than the mesh size.

Most microplastic surface water monitoring data are based on particle sizes greater than 355 µm, but what is known about microplastic toxicity is based on much smaller particle sizes. Particle size distribution models to extrapolate environmental monitoring data to small sizes not captured in environmental sampling have been proposed by Koelmans et al. (2020), and Kooi and Koelmans (2019). These models were recently used by Coffin et al. (2022) to estimate San Francisco Bay particle counts, which, when compared to recently developed thresholds (Mehinto et al., 2022), indicated that more than three-quarters of samples exceeded the most conservative food dilution threshold. However, this risk characterization study has large amounts of uncertainty, as the size distribution models are based on very limited data sets in which data were partly picked to fit the model, had limited to no QA/QC, and were relatively limited in geographic scope. Most of the data were also limited to >100 µm particle sizes, yet were used to extrapolate to much smaller sizes. Therefore, the current size distribution models used to rescale manta trawl data to assess microplastic risk may not accurately represent San Francisco Bay microplastics.

There is a significant need to evaluate the particle size distribution of microplastics in San Francisco Bay to assess the validity and uncertainty of using these models to conduct risk characterization. Understanding the particle size distribution will also help inform future RMP monitoring and study design and science needs. The goal of this study is to collect and evaluate the size distribution of San Francisco Bay surface water microplastics to inform more accurate estimates of microplastic levels in the Bay and future exposure assessments. In addition, this study will help evaluate field sampling methods to better design future monitoring efforts.

The proposed approach is to collect up to nine surface water samples and nine sediment samples from within San Francisco Bay. Samples will be collected in triplicate from three water sites from different subembayments (North, Central, and South Bay) using a modified pump sampling method to collect sufficient water volume through a 10 µm filter to overcome blank contamination issues. If more funding is available, samples will also be collected in triplicate from three sediment sites (one ambient, two margins) using a modified Van Veen sediment grab. Samples will be extracted following accepted methods (ASTM D-8333-20; California State standard methods), and particles down to a size of 10 µm will be characterized using Fourier Transform Infrared Spectroscopy with ultrafast Focal Plane Array detection. The distributions of the number, type (shape, material), and size of microplastics at each site and across sites will be determined. The particle size distributions measured from this proposal will be compared with particle size distribution models proposed and utilized by others (Coffin et al., 2022; Koelmans et al., 2020; Kooi and Koelmans, 2019) to evaluate microplastic exposure and risks. The amount of variation among and between sites will also be used to inform future microplastic monitoring design.

The deliverable for this project would be a final draft short manuscript that will be submitted for peer-review publication.

Budget:

The SFEI labor budget is estimated to be between $55,000 - $80,500. This includes staff time required to develop study design, gather sampling equipment and materials, collect samples, ship samples, data management, data analysis, and reporting of data in a draft and final draft manuscript submitted for publication. A budget on the lower end includes sampling of the water matrix only, while a budget on the higher end includes water and sediment sampling and analysis.

The analytical budget is estimated to be between $7,000 - $17,500. This is based on an estimated cost of $700/sample and analysis of 10 - 25 samples (including QA/QC samples) for water and sediment.

Direct expense is estimated to be between $3,000 - $7,000. This includes equipment and supplies costs needed to collect samples, sample containers, and shipping costs to send samples to the analytical laboratory.

References

Coffin, S., Weisberg, S. B., Rochman, C., Kooi, M., & Koelmans, A. A. (2022). Risk characterization of microplastics in San Francisco Bay, California. *Microplastics and Nanoplastics*, *2*(1), 19. https://doi.org/10.1186/s43591-022-00037-z

Koelmans, A. A., Redondo-Hasselerharm, P. E., Mohamed Nor, N. H., & Kooi, M. (2020). Solving the Nonalignment of Methods and Approaches Used in Microplastic Research to Consistently Characterize Risk. *Environmental Science & Technology*, *54*(19), 12307–12315. https://doi.org/10.1021/acs.est.0c02982

Kooi, M., & Koelmans, A. A. (2019). Simplifying Microplastic via Continuous Probability Distributions for Size, Shape, and Density. *Environmental Science & Technology Letters*, *6*(9), 551–557. https://doi.org/10.1021/acs.estlett.9b00379

Mehinto, A. C., Coffin, S., Koelmans, A. A., Brander, S. M., Wagner, M., Thornton Hampton, L. M., Burton, A. G., Miller, E., Gouin, T., Weisberg, S. B., & Rochman, C. M. (2022). Risk-based management framework for microplastics in aquatic ecosystems. *Microplastics and Nanoplastics*, *2*(1), 17. https://doi.org/10.1186/s43591-022-00033-3

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Spatial variability of sediment accretion in San Francisco Bay restorations

Summary: Over the past 200 years, San Francisco Bay has lost over 80% of its historical salt marshes to diking, salt pond production, and fill. Salt marshes provide critical habitat for protected species, migratory birds, as well as coastal protection. One of the key sediment management questions for San Francisco Bay is whether available sediment is sufficient for planned marsh restoration sites to attain suitable elevations for marsh vegetation establishment and to keep pace with sea-level rise. Although large-scale restoration has been taking place in San Francisco Bay for decades, measurements of decadal-scale rates of accretion within areas where tidal exchange has been restored are limited. We propose to investigate accretion rates for a range of marsh restoration sites and estimate the volume of sediment in those sites. Our overall objectives are to 1) investigate the amount of accretion that has occurred within marsh restorations, 2) investigate the sediment characteristics in restorations, 3) estimate the mass and volume of sediment retained in these restorations; and 4) produce data sets for testing numerical models of sediment transport between the Bay and marsh restorations at 5 restoration marsh sites. Final site selection will be done in coordination with the RMP Sediment Workgroup and the WRMP and will depend on factors such as site accessibility and suitability for the study. Results will be useful for prioritizing marsh restoration sites, understanding bay-wide sediment budgets, and understanding sediment accretion in restorations region-wide, and their resilience to sea-level rise.

Estimated Cost: $203,528
Oversight Group: RMP Technical Review Committee (TRC)

Proposed by: Karen Thorne[1] and Jessie Lacy[2]
[1] USGS Western Ecological Research Center, Davis CA 95616, kthorne@usgs.gov
[2] USGS Pacific Coastal and Marine Science Center, Santa Cruz CA 95060, jlacy@usgs.gov

Proposed Deliverables and Timeline

Based on 24-month project: April 2024 to March 2026

Deliverable	Due Date
Data release: soil properties	September 2025
Data release: digital elevation models and RTK GPS data	September 2025
Report (draft paper):	March 2026
Final Presentation to RMP	Spring or Fall 2026
Presentation to Bay Delta Science or State of the Estuary Conference	2026

Background

Salt marshes provide critical endangered species habitat, sequester carbon, and protect infrastructures and communities from coastal flooding. The lower San Francisco Bay Estuary (hereafter Bay) has lost over 85% of its historical tidal marshes resulting in major declines in wildlife habitat and flood protection potential (Goals Project 2015). An ambitious effort to restore tens of thousands of acres of salt marshes across the Bay is underway, supported by federal, state, and local entities. Most restoration projects are carried out by breaching levees to restore tidal exchange to diked former marshes that were converted to agriculture or salt ponds and subsequently subsided. As accretion occurs, elevations can reach a point where marsh vegetation can become established which typically increases accretion rates by trapping suspended sediment and contributing below ground organic matter. However, the combination of sea-level rise (SLR, Thorne et al. 2018) and declining sediment supply to the Bay in recent decades (Schoellhamer 2011) presents a threat to restoration goals as well as to existing marshes. Ecological modeling of Bay marshes predicts significant marsh loss by 2100 (Takekawa et al. 2013), but the extent of predicted loss depends on the rate of SLR and the magnitude of sediment supply (e.g., Buffington et al. 2021). The projected supply of sediment to the Bay from the Delta and local tributaries is much less than needed for existing Baylands to keep up with projected sea level rise by 2100, and the deficit is much greater when sediment required for current restoration goals is considered (Dusterhoff et al., 2021).

One of the key sediment management questions in the Bay is whether available sediment is reaching restoration sites and whether accretion is sufficient for restored marshes to build elevations to reach a vegetated state and keep pace with relative SLR, and to support planned restoration goals. A second question is the magnitude of the sediment sink produced by wetland restoration, and how it might influence the sediment budget of the Bay or of individual embayments. Sediment availability to marshes varies spatially, and in a general sense depends on the magnitude of suspended-sediment concentration (SSC) in adjacent shallows. However, variation in processes that deliver sediment from Bay channels into the shallows and marshes, including tides, wave-driven resuspension, edge erosion, and vegetative trapping, can influence marsh accretion. These processes vary spatially, with proximity to sediment source (Delta or Bay tributary), wave exposure, marsh type, and marsh topography, and temporally, due to variation in physical forcing on spring-neap, storm event, and seasonal time scales, as well as seasonal variation in vegetation (Buffington et al. 2020, Lacy et al. 2018, Lacy et al. 2020). As a result, we expect decadal-scale accretion to vary geographically in the Bay. Understanding this variation is important for future restoration planning and design and understanding Bay-wide sediment budgets now and into the future.

We propose to determine the magnitude and rate of decadal-scale sedimentation in a range of marsh restorations using three approaches: 1) determine total depth of sedimentation since restoration and accretion rates by collecting sediment cores and identifying the pre-restoration surface, 2) determine volumes of sedimentation and volumetric accretion rates by differencing digital elevation models based on existing data (10 years old or more) and on RTK GPS surveys collected in this project, and 3) estimate volumetric accretion rates by interpreting remote sensing imagery based on known elevations of colonization by species of marsh vegetation (primarily *Spartina* and *Sarcocornia*). Core segments will be analyzed for bulk density, allowing the volumetric estimates to be converted to mass accretion rates. Results will be synthesized to investigate relationships between restoration age, location, degree of subsidence, vegetation, and distance from sediment source with rates of mass and volumetric sediment accretion. Results will be useful for calibrating and validating hindcast models of marsh evolution.

Study Questions and Applicable RMP Management Questions

The proposed work aims to address the following questions:

1. What are the accretion rates in marsh restorations?
2. What is the volume and mass of sediment in marsh restorations?
3. Are these values related to restoration age, location, vegetation, distance from sediment source?
4. Will sediment accretion in restorations be adequate to create and support emergent tidal vegetated habitat?

This project addresses San Francisco Bay Regional Monitoring Program (RMP) Sediment Workgroup Management question 4 (Table 1). It also informs the *Flux on shoals and into wetlands* priority identified in the Sediment Workgroup's Sediment Monitoring and Modeling Strategy (McKee et al. 2020).

RMP Sediment Workgroup management questions and associated study questions

Management question	Study question	Example information application
MQ4: How much sediment is passively reaching tidal marshes and restoration projects, and how could the amounts be increased by management actions?	1,2,3,4	● Understanding magnitude of sediment sink produced by (or conversely magnitude of sediment supply required by) marsh restoration ● Prioritizing restoration sites ● Predicting marsh evolution

Approach

Task 1. Site selection
We will select 5 marsh restoration sites across the Bay to provide a comparative framework. In selecting sites, we will consult with the RMP Sediment Workgroup, WRMP Technical Advisory Team, and SBSPRP Project Management Team. Final site selection is subject to review of existing data and field reconnaissance, as well as feasibility of access permissions, endangered species restrictions, and funding. Additional study sites could be added with matching funds. Site selection will be completed by June 2024.

Site selection criteria includes:

- Passive sediment supply, with no placement of fill before breaching.
- Range of geographic locations/embayment in the Bay
- Range of age of restoration
- Availability of elevation data either pre-restoration or at least 10 years ago and other relevant data.

Candidate sites are below and Figure 1: **denotes sites where PIs have historical data*

Site A: Pond A6 (South Bay)– Pond A6 is owned and managed by the USFWS and is part of the SBSPRP and was breached in 2010. Sediment accretion monitoring occurred between 2010 and 2013 (Callaway et al. 2013). However, elevation gains (deposition of suspended sediment and in situ organic matter accumulation) have not been measured since 2013. Callaway has agreed to share existing data. WRMP priority Project monitoring site in Santa Clara Valley.

***Site B: Cargill Marsh** (South Central East Bay) – This restoration is a part of the Eden Landing Ecological Reserve and was restored in 1998. This marsh is adjacent to Whale's Tail south study site for our 2020 RMP Special Study. We have collected one core and some RTK GPS data at this site, as well as some measurements of water and sediment flux to the site. WRMP priority Reference site in Alameda Creek network.

Site C: Faber-Laumeister Marshes (South Central West) – This marsh was restored around 1969-1971 and is adjacent to Palo Alto. Elevation and vegetation surveys were done in 2009 for comparisons (Takekawa et al. 2013). WRMP secondary priority network, but Laumeister marsh is a Benchmark site and Faber a Reference site.

Site D: Bahia Wetland (North Bay, Petaluma River) - The Bahia Wetland restoration includes approximately 400 acres of tidal marsh and was breached in 2008. Post-project monitoring has occurred; however, reports are not readily available online.

Site E: Outer Muzzi Marsh (Central Bay) – This marsh was restored in 1976 and is part of the Corte Madera Ecological Reserve. Inner Muzzi marsh used dredged sediments. One of our 2022 RMP Special Study sites. WRMP secondary priority Project site.

***Site F: Tolay Creek** (North Bay) – This restoration occurred in 1997 with reconnections to San Pablo Bay with the breaching of diked agriculture lands. There is existing monitoring data pre and post breach (Takekawa et al. 2014). We plan to core and conduct elevation surveys here in summer of 2023 for a funded project assessing long-fin smelt habitat and food webs. WRMP undesignated Project site.

Site G: Pond 3 (North East Bay, Napa River) - This restoration is part of the Napa-Sonoma Marshes Wildlife Area and was breached in 2002. Existing monitoring data is available for elevation and vegetation (Takekawa et al. 2005, Brand et al. 2012). WRMP Project site.

Site H: Pond 2A (North East Bay, Napa River) - This restoration is part of the Napa-Sonoma Marshes Wildlife Area and was breached in 1995. Monitoring data may exist but reports still need to be located (Parker et al., Takekawa et al.)

Site I: Tubbs Island Setback (North Bay) – This restoration is part of the San Pablo Bay NWR and reconnection to San Pablo Bay occurred in 2002 (Woo et al. 2007).

Site J: Carl’s marsh (North Bay, Petaluma River) – This marsh was restored in 1994 by the Sonoma Land Trust. Monitoring data may exist (e.g., Siegal 2002).

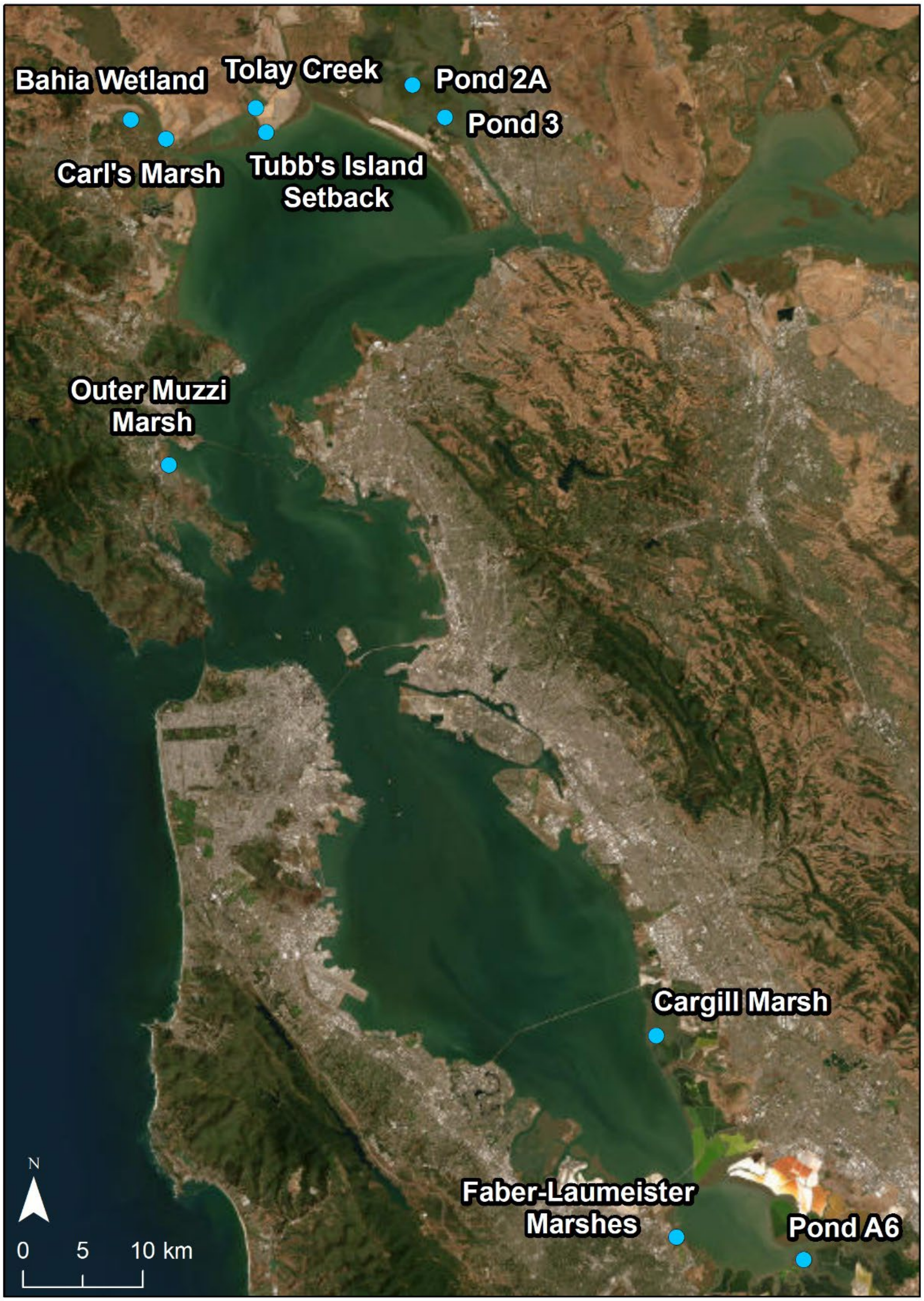

Figure 1. Candidate wetland restoration sites for the study

Task 2. Evaluate existing datasets:

a. Remote sensing data – We will collate existing remotely sensed data, including 2004, 2010, and 2018 existing lidar datasets (from DWR, USGS, NOAA) which will be compared with field topography surveys (Task 3). Since vegetation recruitment in a restoration can be used as a surrogate for elevation, we will use historical imagery (e.g., Landsat, NAIP) to identify years of plant establishment and expansion.
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Spatial variability of sediment accretion in San Francisco Bay restorations

Summary: Over the past 200 years, San Francisco Bay has lost over 80% of its historical salt marshes to diking, salt pond production, and fill. Salt marshes provide critical habitat for protected species, migratory birds, as well as coastal protection. One of the key sediment management questions for San Francisco Bay is whether available sediment is sufficient for planned marsh restoration sites to attain suitable elevations for marsh vegetation establishment and to keep pace with sea-level rise. Although large-scale restoration has been taking place in San Francisco Bay for decades, measurements of decadal-scale rates of accretion within areas where tidal exchange has been restored are limited. We propose to investigate accretion rates for a range of marsh restoration sites and estimate the volume of sediment in those sites. Our overall objectives are to 1) investigate the amount of accretion that has occurred within marsh restorations, 2) investigate the sediment characteristics in restorations, 3) estimate the mass and volume of sediment retained in these restorations; and 4) produce data sets for testing numerical models of sediment transport between the Bay and marsh restorations at 5 restoration marsh sites. Final site selection will be done in coordination with the RMP Sediment Workgroup and the WRMP and will depend on factors such as site accessibility and suitability for the study. Results will be useful for prioritizing marsh restoration sites, understanding bay-wide sediment budgets, and understanding sediment accretion in restorations region-wide, and their resilience to sea-level rise.

Estimated Cost: $203,528
Oversight Group: RMP Technical Review Committee (TRC)

Proposed by: Karen Thorne[1] and Jessie Lacy[2]
[1] USGS Western Ecological Research Center, Davis CA 95616, kthorne@usgs.gov
[2] USGS Pacific Coastal and Marine Science Center, Santa Cruz CA 95060, jlacy@usgs.gov

Proposed Deliverables and Timeline

Based on 24-month project: April 2024 to March 2026

Deliverable	Due Date
Data release: soil properties	September 2025
Data release: digital elevation models and RTK GPS data	September 2025
Report (draft paper):	March 2026
Final Presentation to RMP	Spring or Fall 2026
Presentation to Bay Delta Science or State of the Estuary Conference	2026

Background

Salt marshes provide critical endangered species habitat, sequester carbon, and protect infrastructures and communities from coastal flooding. The lower San Francisco Bay Estuary (hereafter Bay) has lost over 85% of its historical tidal marshes resulting in major declines in wildlife habitat and flood protection potential (Goals Project 2015). An ambitious effort to restore tens of thousands of acres of salt marshes across the Bay is underway, supported by federal, state, and local entities. Most restoration projects are carried out by breaching levees to restore tidal exchange to diked former marshes that were converted to agriculture or salt ponds and subsequently subsided. As accretion occurs, elevations can reach a point where marsh vegetation can become established which typically increases accretion rates by trapping suspended sediment and contributing below ground organic matter. However, the combination of sea-level rise (SLR, Thorne et al. 2018) and declining sediment supply to the Bay in recent decades (Schoellhamer 2011) presents a threat to restoration goals as well as to existing marshes. Ecological modeling of Bay marshes predicts significant marsh loss by 2100 (Takekawa et al. 2013), but the extent of predicted loss depends on the rate of SLR and the magnitude of sediment supply (e.g., Buffington et al. 2021). The projected supply of sediment to the Bay from the Delta and local tributaries is much less than needed for existing Baylands to keep up with projected sea level rise by 2100, and the deficit is much greater when sediment required for current restoration goals is considered (Dusterhoff et al., 2021).

One of the key sediment management questions in the Bay is whether available sediment is reaching restoration sites and whether accretion is sufficient for restored marshes to build elevations to reach a vegetated state and keep pace with relative SLR, and to support planned restoration goals. A second question is the magnitude of the sediment sink produced by wetland restoration, and how it might influence the sediment budget of the Bay or of individual embayments. Sediment availability to marshes varies spatially, and in a general sense depends on the magnitude of suspended-sediment concentration (SSC) in adjacent shallows. However, variation in processes that deliver sediment from Bay channels into the shallows and marshes, including tides, wave-driven resuspension, edge erosion, and vegetative trapping, can influence marsh accretion. These processes vary spatially, with proximity to sediment source (Delta or Bay tributary), wave exposure, marsh type, and marsh topography, and temporally, due to variation in physical forcing on spring-neap, storm event, and seasonal time scales, as well as seasonal variation in vegetation (Buffington et al. 2020, Lacy et al. 2018, Lacy et al. 2020). As a result, we expect decadal-scale accretion to vary geographically in the Bay. Understanding this variation is important for future restoration planning and design and understanding Bay-wide sediment budgets now and into the future.

We propose to determine the magnitude and rate of decadal-scale sedimentation in a range of marsh restorations using three approaches: 1) determine total depth of sedimentation since restoration and accretion rates by collecting sediment cores and identifying the pre-restoration surface, 2) determine volumes of sedimentation and volumetric accretion rates by differencing digital elevation models based on existing data (10 years old or more) and on RTK GPS surveys collected in this project, and 3) estimate volumetric accretion rates by interpreting remote sensing imagery based on known elevations of colonization by species of marsh vegetation (primarily *Spartina* and *Sarcocornia*). Core segments will be analyzed for bulk density, allowing the volumetric estimates to be converted to mass accretion rates. Results will be synthesized to investigate relationships between restoration age, location, degree of subsidence, vegetation, and distance from sediment source with rates of mass and volumetric sediment accretion. Results will be useful for calibrating and validating hindcast models of marsh evolution.

Study Questions and Applicable RMP Management Questions

The proposed work aims to address the following questions:

1. What are the accretion rates in marsh restorations?
2. What is the volume and mass of sediment in marsh restorations?
3. Are these values related to restoration age, location, vegetation, distance from sediment source?
4. Will sediment accretion in restorations be adequate to create and support emergent tidal vegetated habitat?

This project addresses San Francisco Bay Regional Monitoring Program (RMP) Sediment Workgroup Management question 4 (Table 1). It also informs the *Flux on shoals and into wetlands* priority identified in the Sediment Workgroup's Sediment Monitoring and Modeling Strategy (McKee et al. 2020).

RMP Sediment Workgroup management questions and associated study questions

Management question	Study question	Example information application
MQ4: How much sediment is passively reaching tidal marshes and restoration projects, and how could the amounts be increased by management actions?	1,2,3,4	● Understanding magnitude of sediment sink produced by (or conversely magnitude of sediment supply required by) marsh restoration ● Prioritizing restoration sites ● Predicting marsh evolution

Approach

Task 1. Site selection
We will select 5 marsh restoration sites across the Bay to provide a comparative framework. In selecting sites, we will consult with the RMP Sediment Workgroup, WRMP Technical Advisory Team, and SBSPRP Project Management Team. Final site selection is subject to review of existing data and field reconnaissance, as well as feasibility of access permissions, endangered species restrictions, and funding. Additional study sites could be added with matching funds. Site selection will be completed by June 2024.

Site selection criteria includes:

- Passive sediment supply, with no placement of fill before breaching.
- Range of geographic locations/embayment in the Bay
- Range of age of restoration
- Availability of elevation data either pre-restoration or at least 10 years ago and other relevant data.

Candidate sites are below and Figure 1: **denotes sites where PIs have historical data*

Site A: Pond A6 (South Bay)– Pond A6 is owned and managed by the USFWS and is part of the SBSPRP and was breached in 2010. Sediment accretion monitoring occurred between 2010 and 2013 (Callaway et al. 2013). However, elevation gains (deposition of suspended sediment and in situ organic matter accumulation) have not been measured since 2013. Callaway has agreed to share existing data. WRMP priority Project monitoring site in Santa Clara Valley.

***Site B: Cargill Marsh** (South Central East Bay) – This restoration is a part of the Eden Landing Ecological Reserve and was restored in 1998. This marsh is adjacent to Whale's Tail south study site for our 2020 RMP Special Study. We have collected one core and some RTK GPS data at this site, as well as some measurements of water and sediment flux to the site. WRMP priority Reference site in Alameda Creek network.

Site C: Faber-Laumeister Marshes (South Central West) – This marsh was restored around 1969-1971 and is adjacent to Palo Alto. Elevation and vegetation surveys were done in 2009 for comparisons (Takekawa et al. 2013). WRMP secondary priority network, but Laumeister marsh is a Benchmark site and Faber a Reference site.

Site D: Bahia Wetland (North Bay, Petaluma River) - The Bahia Wetland restoration includes approximately 400 acres of tidal marsh and was breached in 2008. Post-project monitoring has occurred; however, reports are not readily available online.

Site E: Outer Muzzi Marsh (Central Bay) – This marsh was restored in 1976 and is part of the Corte Madera Ecological Reserve. Inner Muzzi marsh used dredged sediments. One of our 2022 RMP Special Study sites. WRMP secondary priority Project site.

***Site F: Tolay Creek** (North Bay) – This restoration occurred in 1997 with reconnections to San Pablo Bay with the breaching of diked agriculture lands. There is existing monitoring data pre and post breach (Takekawa et al. 2014). We plan to core and conduct elevation surveys here in summer of 2023 for a funded project assessing long-fin smelt habitat and food webs. WRMP undesignated Project site.

Site G: Pond 3 (North East Bay, Napa River) - This restoration is part of the Napa-Sonoma Marshes Wildlife Area and was breached in 2002. Existing monitoring data is available for elevation and vegetation (Takekawa et al. 2005, Brand et al. 2012). WRMP Project site.

Site H: Pond 2A (North East Bay, Napa River) - This restoration is part of the Napa-Sonoma Marshes Wildlife Area and was breached in 1995. Monitoring data may exist but reports still need to be located (Parker et al., Takekawa et al.)

Site I: Tubbs Island Setback (North Bay) – This restoration is part of the San Pablo Bay NWR and reconnection to San Pablo Bay occurred in 2002 (Woo et al. 2007).

Site J: Carl's marsh (North Bay, Petaluma River) – This marsh was restored in 1994 by the Sonoma Land Trust. Monitoring data may exist (e.g., Siegal 2002).

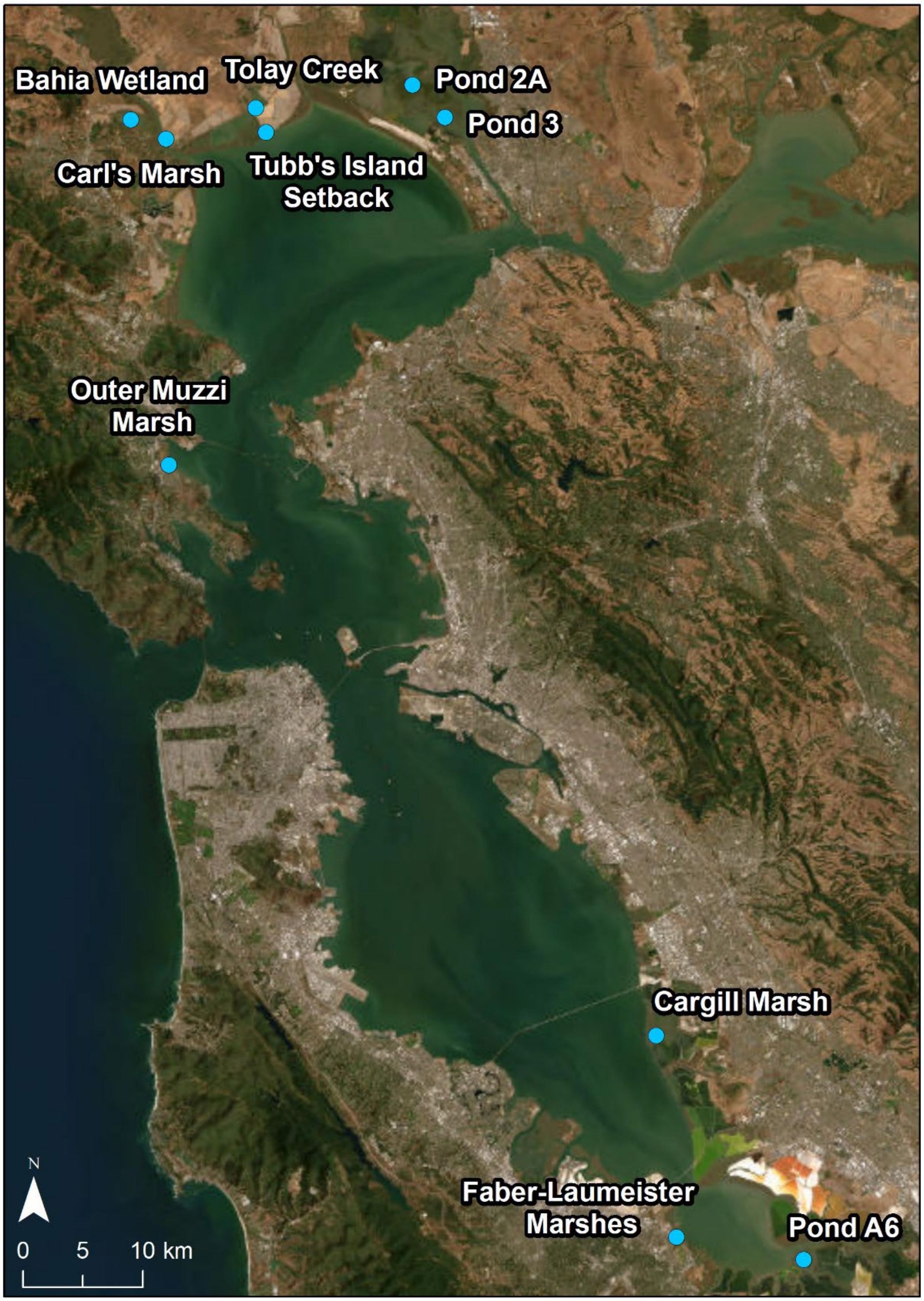

Figure 1. Candidate wetland restoration sites for the study

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RMP Special Study Proposal: Continuous Suspended Sediment Concentration and Wave Monitoring in South and Lower South San Francisco Bay - Year 3

Summary: The collection of continuous suspended sediment concentration (SSC) and wave data in shallow areas of South and Lower South San Francisco Bay (SB and LSB, respectively) was funded by the South Bay Salt Pond Restoration Project in 2022 and the Regional Monitoring Program in 2023. This past work enabled the development of preliminary turbidity-SSC calibrations for eight stations spanning a range of Bay environments (channel, shoal, and slough) from the San Mateo Bridge to Alviso Slough. This proposed project would support continued data collection and calibration refinement for an additional seven months in 2024, which is needed to develop robust turbidity-SSC relationships. Once completed, these site-specific calibrations will expand continuous SSC monitoring to shallow areas of the SB and LSB, which play an important yet understudied role in Bay sediment dynamics. The collection of high frequency wave data will further inform sediment dynamics on the shoal, which are strongly influenced by wind waves. This project will support the maintenance of instruments and collection of SSC samples from the recently established SB shoal turbidity station directly offshore from Eden Landing, and collection of SSC samples at seven pre-existing turbidity stations, several of which have been collecting turbidity data since 2015. The existing turbidity stations and SSC sampling at four SB stations are supported by the Nutrient Management Strategy (NMS). By leveraging existing NMS instrumentation and field servicing, this project would significantly expand available SSC data in SB and LSB at a considerably lower cost than independently implementing additional sediment monitoring stations.

There are two proposed tiers of work for the third year of the project.

Tier 1 includes:

- Ongoing collection and processing of SSC samples at four stations in LSB and maintenance of one SB shoal turbidity station and wave sensor. The collection of SSC samples by the NMS at four additional stations will also be leveraged for calibration development.
- Development of site-specific turbidity-SSC relationships at eight stations in SB and LSB.
- Curation of resulting SSC time series from all eight stations and data sharing for RMP related applications.
- Curation and data sharing of wave height and period data from one shoal station in SB.

Tier 2 includes all Tier 1 activities plus:

- Further refinement of site-specific turbidity-SSC relationships, including comprehensive reporting.

Estimated Cost: Tier 1: $64,919 Tier 2: $78,873

Oversight Group: Sediment Workgroup

Proposed by: Lilia Mourier (SFEI), Martin Volaric (SFEI), and Ariella Chelsky (SFEI)

Proposed Deliverables and Timeline

Deliverable	Due Date
Datasets: 15-minute turbidity and SSC time series data from eight stations in South Bay and Lower South Bay and wave height and period data from one station in South Bay. Data files (e.g., ..csv) will be shared with RMP.	As calibrations come online and QAQC'd data are available, beginning summer 2024
Report detailing data collection and turbidity-to-SSC calibrations	Fall 2024
Project update presentation to the RMP Sediment Workgroup	Spring 2025

Project Background and Overview

Suspended sediment dynamics are relevant to a range of San Francisco Bay (SFB) water quality, ecological, and morphological processes. Despite decades of studies pointing to the importance of sediment dynamics to South Bay and Lower South Bay (SB and LSB, respectively) ecosystem processes and water quality management, continuous suspended sediment concentration (SSC) data are currently only available within the SB channels. Calibrating models to simulate complex sediment dynamics requires knowledge of time-varying SSC spanning multiple morphological regions. Sediment-related empirical studies may directly rely on continuous SSC measurements, leverage output from sediment transport models calibrated to SSC measurements, and/or benefit from well-characterized background SSC conditions. The expansion of continuous SSC monitoring is therefore essential to advancing SFB planning and management related to a range of concerns, including contaminant transport, primary productivity, biogeochemical/nutrient cycling, and sea level rise resilience. Historical contaminant loading, a heavily urbanized bayfront, and severe nutrient enrichment make these concerns particularly relevant in SB and LSB.

This project will continue to fill SSC data gaps cost-efficiently in SB and LSB by leveraging existing sensor stations and servicing associated with the San Francisco Bay Nutrient Management Strategy (NMS; Table 1 and Figure 1). The NMS currently supports eight continuous monitoring sites throughout SB and LSB. We propose building on two years of SSC data that are being used to develop the turbidity-SSC calibration at seven of these sites (listed in Table 1), along with the newly installed Eden Landing station (EDL in Figure 1). We exclude the NMS Dumbarton station because the USGS California Water Science Center (USGS-CAWSC) has developed a calibration for that station. The NMS Pond A8 Outlet station is confounded by sediment inflow from multiple water sources, and was also excluded from the calibration.

The four SB NMS stations north of the San Mateo Bridge (HAY, SHL, SLM, SMB) are serviced monthly as part of a collaboration with the USGS-CAWSC. Turbidity data collection at SMB dates back to 2015; turbidity sensors were deployed at the other three sites in 2020. Monthly SSC sampling began at all four stations in late 2020 and is ongoing. Ongoing station maintenance and SSC sample collection and analysis is supported by the NMS. This project would support the addition of particle size analysis to SSC samples already being collected at these four stations by the NMS, as well as turbidity-SSC calibrations and the resulting SSC time series dataset.

The three existing project-relevant Lower South Bay stations (ALV, GUAD, NW) have been deployed since 2015 and are serviced monthly as part of a collaboration between the NMS and the USGS Pacific and Coastal Marine Facility (USGS-MarFac). This project would support SSC sample collection (including particle size analysis), turbidity-SSC calibrations, and the SSC time series data from these three sites.

Table 1 – Summary of existing and proposed turbidity-SSC calibrations at suspended sediment monitoring stations in South and Lower South San Francisco Bay. All stations measure turbidity at a 15-minute time step; the SSC sampling interval is approximately monthly. Efforts supported by this proposal are shaded in gray.

Site	Program	Data Range	SSC Sampling	Turbidity -SSC Calibration	Instrument Orientation	Instrument(s)
Alviso Slough (ALV)	NMS/RMP	2015-present	Current	Ongoing	50 cm above bottom	YSI EXO2
Guadalupe Slough (GUAD)	NMS/RMP	2015-present	Current	Ongoing	50 cm above bottom	YSI EXO2
Newark Slough (NEW)	NMS/RMP	2015-present	Current	Ongoing	50 cm above bottom	YSI EXO2
Hayward (HAY)	NMS	2020-present	Current	Ongoing	1 m above bottom	YSI EXO2, RBR Solo3
San Leandro Marina (SLM)	NMS	2020-present	Current	Ongoing	1.3 m above bottom	YSI EXO2
Shoal Buoy (SHL)	NMS	2020-present	Current	Ongoing	80 cm below surface	YSI EXO2
San Mateo Bridge (SMB)	NMS	2015-present	Current	Ongoing	10 m above bottom	YSI EXO2
Dumbarton Bridge (DMB)	USGS-CAWSC	2010-present	Current	Existing	1.2, 7.6 m above bottom	YSI EXO2
Eden Landing (EDL)	NMS/RMP	2022-present	Current	Ongoing	50 cm above bottom	PME/Turner Cyclops 7

Two stations were added to the network in 2022 with funding from the South Bay Salt Ponds Restoration Project and monitoring of these stations continued in 2023 with funding from the Regional Monitoring Program (Table 1). A monitoring station was added in January 2022 directly offshore from the Eden Landing "Whale's Tail" area, the site of a RMP-funded study on sediment accretion and erosion in intertidal marsh conducted by the USGS (PIs Jessie Lacy and Karen Thorne). A single parameter turbidity sensor deployed at this station is serviced during monthly NMS servicing trips. Additionally, a pressure sensor measuring wave height and period was deployed at the Hayward station ("RBR Solo3" in Table 1). Recent deployment data from HAY (Figure 2) and published studies (e.g., May et al. 2003, Thompson et al. 2008) point to the importance of wind waves on sediment dynamics on the shoal.

This project relies on calibrating optical-sensor turbidity signals to SSC measurements, and a minimum number of SSC samples (dependent on the range of sampled conditions) is needed to generate a reliable calibration (Rasmussen et al. 2009). Typically ~30 samples per site from a range of conditions are required for a reliable calibration. Thus, to make the most of the data collected in the first and second year of the project, an additional seven months of funding are requested.

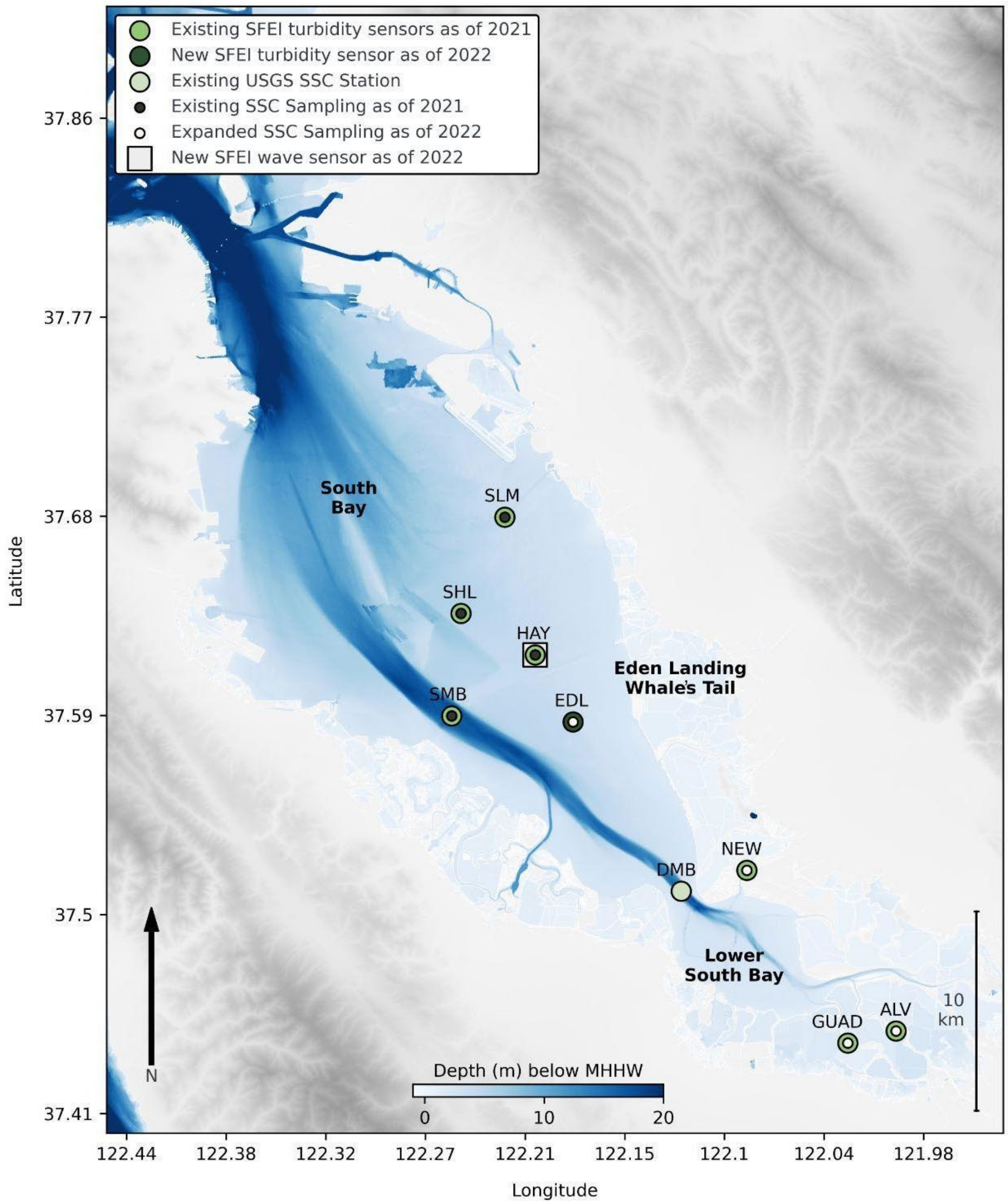

Figure 1 – Map of existing turbidity sensors and SSC sampling as of 2021 and newly expanded turbidity monitoring and SSC sampling as of 2022 in South Bayand Lower South Bay. Note that the USGS Dumbarton Bridge Station (DMB) has an existing turbidity-to-SSC calibration; SSC concentrations are reported from the turbidity sensor here. See Table 1 for site details and abbreviation reference.

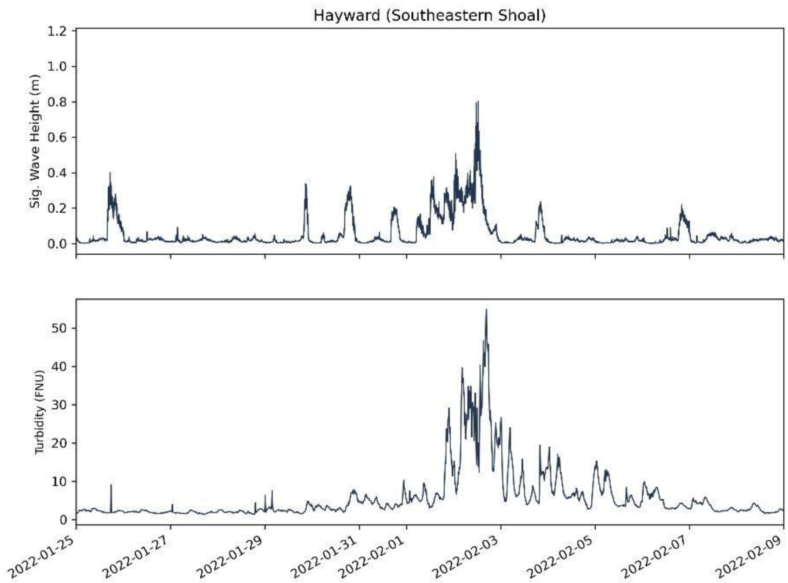

Figure 2 – Example turbidity and significant wave height data from the HAY station.

Study Objectives and Applicable RMP Management Questions

The study will provide essential information for addressing Management Questions #4 and #5 from the RMP Sediment Workgroup (Table 2).

Table 2. Study objectives relevant to the Sediment Workgroup management questions.

Management Question	Study Objective	Example Information Application
4) How much sediment is passively reaching tidal marshes and restoration projects and how could the amounts be increased by management actions?	● Expand continuous monitoring of suspended sediment concentrations in South and Lower South San Francisco Bay	● Empirical studies of marsh accretion/erosion requiring knowledge of SSC in the adjacent water column
5) What are the concentrations of suspended sediment in the Estuary and its segments?	● Expand continuous monitoring of suspended sediment concentrations in South and Lower South San Francisco Bay ● Measure wave height and period at one South Bay shoal station ● Curated SSC and wave dataset	● Calibration of any sediment transport models and associated applications ● Empirical studies of marsh accretion/erosion requiring knowledge of SSC in the adjacent water column

Approach for 2023

There are two proposed tiers of work for this third year of the project, which differ in scope and cost.

<u>Tier 1</u>

Task 1 - Continue to maintain turbidity stations in South Bay and Lower South Bay (Requested RMP funding for one station)

Seven existing turbidity stations will continue to be maintained monthly as part of NMS-funded station servicing trips. RMP funds would support the recently established SB shoal turbidity station offshore Eden Landing, which will continue to be maintained monthly for the duration of the project and will be retired in July 2024. During each servicing trip, instruments at 3-5 stations are swapped for lab-cleaned and calibrated instruments. The remaining stations are field serviced, including thorough cleaning, calibration checks, and battery replacement.

Task 2 – Continue to maintain pressure sensor (Requested RMP funding)

The RBR Solo3 wave sensor deployed at the Hayward shoal station will continue to be maintained during standard NMS station servicing trips for the duration of the project and will be retired in July 2024. The pressure sensor is set to burst at 4 Hz for 1 minute intervals every 5 minutes. This sensor will continue to be cleaned during monthly NMS station servicing. Data are offloaded from the sensor every other servicing trip.

Task 3 – Continue SSC sampling at all sites (Requested RMP funding for four stations)

SFEI field staff will continue to collect SSC samples at LSB sites (ALV, GUAD, NEW, EDL) as part of monthly servicing trips for the duration of the project. SSC sampling for this project will end in July 2024, upon reaching the target total discrete sample count for each site-specific calibration. Samples will be collected at the approximate instrument elevation using a Van Dorn sampler following standard USGS procedure. SSC sampling is conducted by the USGS-CAWSC staff at SMB, SHL, HAY, and SLM stations during SB servicing trips and supported by the NMS. All SSC samples will be processed at the USGS Santa Cruz Sediment Laboratory. Samples will also undergo particle size analysis to determine the fraction of sand versus fine sediment in suspension.

Task 4 - General data processing and curation (Requested RMP funding for two stations)

Turbidity and wave data will be processed through a multi-level procedure that includes statistical filtering and manual review.

Task 5 – Generate site-specific turbidity-SSC calibrations (Requested RMP funding)

Site-specific turbidity-SSC calibrations will be developed based on sensor turbidity and SSC sample data using both simple linear regression models (Rasmussen et al. 2009), and a linear mixed effect model (see Task 8 below). SSC samples will be collected at monthly intervals. Sufficient variability in observed SSC will be needed to generate reliable calibrations. We estimate that at least 30 SSC samples will be needed to generate a reliable calibration. Twenty-seven samples will be collected during the first 2 project years; we propose collecting an additional seven samples because many of the samples already collected have been during low turbidity conditions. Calibrations between SSC and turbidity will be completed following full QA/QC of turbidity data and will be made available to the RMP.

Task 6 – Create shareable SSC and wave datafiles for RMP (Requested RMP funding)

We will share data generated for this project in .csv format with the RMP as sample data become sufficient to generate reliable calibrations. Available data include discrete SSC and size fraction results, SSC time series, and wave statistic time series.

Task 7 - Presentation and report to RMP Sediment Workgroup (Requested RMP funding)

We will prepare a brief report on the calibration results for the RMP Sediment Workgroup and present the findings to the Workgroup in Spring 2025 to evaluate the need for additional SSC data.

Tier 2

Includes Tasks 1 through 7 plus one additional task (Task 8).

Task 8 - In depth development of calibration and comprehensive reporting

Additional funds would support an in-depth analysis of the turbidity-SSC relationship and the development and comparison of calibrations generated using different analyses. USGS methodology for SSC calibrations utilizes either single linear regression models based on turbidity (SSC vs. turbidity), or multiple linear regression models based on turbidity and a limited number of other environmental variables (e.g. SSC vs. turbidity and chl a). USGS also tests log10 transformations of these models, and unique models are created for each site. These funds would allow for the comparison of several model types (linear, log-log, multiple regression).

Additionally, we plan to more thoroughly test a linear mixed effect (LME) model, which we began developing during year 2 of the project. LMEs are powerful tools that assume similarity in x-y relationships across a range of sample groups. They are similar to the simple linear regression models developed by the USGS, but have the advantage of more efficiently utilizing a limited number of datapoints. For example, in our case the SSC-turbidity relationship is likely to be similar across all sites in SB and LSB. An LME leverages this similarity to create individual models for each site based on data from all sites.

This task also includes additional support for reporting and interpretation of these and other results. Years 1 and 2 of the project only funded short report-outs of the data. This additional task would allow more comprehensive reporting along with synthesis and interpretation of the dataset.

Budget

This proposal piggybacks on existing NMS servicing trips and, accordingly, is a cost-efficient approach to expanding SSC monitoring in South Bay and Lower South Bay. The budget tables show costs for year 3 (Table 3) and the NMS cost-share for Tasks 1, 3, and 4 (Table 4).

Table 3. Year 3 RMP budget.

Project Area		**Tier 1**	**Tier 2**
Tasks		1-7	1-8
Labor	Project management	$10,000	$10,000
	Field and lab work	$12,402	$12,402
	Data management	$13,372	$16,022
	Reporting and presentations	$12,962	$24,312
Direct Expenses	Equipment and supplies	$805	$805
Contracts	USGS-CAWSC	$3,029	$3,029
	USGS-Sed Lab	$4,667	$4,667
	USGS-MarFac	$7,636	$7,636
	Total Year 3	**$64,919**	**$78,873**

Table 4. NMS cost-share.

Item	**Total Cost**	**Note**
Service existing "upper" South Bay stations with USGS-CAWSC	$95,600	Includes boat, USGS personnel, SFEI personnel, and SSC sample collection and processing.
Servicing existing Lower South Bay stations	$57,300	Includes boat, USGS personnel, and SFEI personnel.
Project management for the eight stations included in the project	$25,80	Overall project management costs for NMS moored sensor program.
Field prep, lab time, and data handling for eight stations	$216,100	Field preparation, lab calibration, data processing for all stations.
Existing instrumentation, mounting frames, and field equipment	$240,000	Estimate for 12 EXO2s plus additional pieces of equipment.
Total	$611,580	

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RMP Special Study Proposal: Sediment load from Bay area watersheds under future climate

Summary

Sediment is a critical resource that is essential for sustaining San Francisco Bay tidal marshes and mudflats (or baylands) under a changing climate. "How will watershed load to the Bay change in relation to changing climate, vegetation cover, and land use?" is ranked as a high priority sub management question by Sediment Workgroup. With the development of the Bay regional watershed dynamic model (WDM) (Zi et al., 2021, 2022), the impact of climate change on erosion and sediment transport processes in watersheds can now be assessed in a dynamic manner. We propose to use WDM with downscaled climate model predictions to estimate sediment loadings from two operational landscape units (OLUs, Alameda, Napa and Sonoma) under 20 future climate scenarios. This will be coupled with a sensitivity analysis to assess the influence of vegetation cover and land use on sediment delivery downstream. The results of this study will help address SedWG's high-priority management questions, including: 'How will the load to the Bay from the watershed change in response to changing climate, vegetation cover, and land use?' The study will establish a link between watershed loads and sediment supply to downstream baylands that they will need to help them pace with sea-level rise (SLR).

Estimated Cost $82,325

Time sensitive No

Oversight Group Sediment Workgroup

Proposed by Tan Zi, Kyle Stark, Pedro Avellaneda, Lester McKee, and Scott Dusterhoff (SFEI)

Proposed Deliverables and Timeline

Deliverable	Due Date
Progress presentation at the spring Sediment Workgroup meeting	Spring 2024
Technical report submitted to Sediment Workgroup	Winter 2024

Project Background and Overview

Sediment is a critical resource that is essential for sustaining San Francisco Bay tidal marshes and mudflats (or baylands) under a changing climate. Currently, there are approximately 80,000 acres of baylands that will need an increased sediment supply to keep pace with sea-level rise. In addition, tens of thousands of acres of restored tidal marsh planned throughout the Bay will need sediment to fill subsided areas and maintain tidal marsh elevation into the future.

One of the priority recommendations for additional sediment studies, as identified by the RMP Sediment Modeling and Monitoring Strategy (McKee et al., 2020), is to understand the sediment flux to tidal wetlands. Recently, the Sediment Workgroup has identified the changing relationship between watershed load to the Bay, and climate, vegetation cover, and land use as a high-priority sub-management question. Baylands OLUs, defined as connected areas along the shoreline of San Francisco Bay with specific physical characteristics, should be managed as coherent units for nature-based sea-level rise adaptation. Crucial resources for OLUs to adapt to sea-level rise are sediment supplies from watersheds. Predicting changes in sediment supply over time can allow for better management preparation.

Recently, Dusterhoff et al. (2021) provided estimates of future Bay tributary sediment supply over the next several decades. However, those estimates account for only two future climate scenarios and were annual rates based on a static relationship between annual flow and sediment loads, thereby ignoring the impacts of discrete large storm events on sediment transport dynamics. Soil erosion and sediment transport in a watershed are sensitive to extreme flow events, both the intensity and the frequency of which are expected to be changed under future climate projections, thus a changing the relationship between load and flow is more likely. In addition, Dusterhoff et al. (2021) were not able to confidently resolve sediment load estimates at the spatial scales of marsh restoration. With the development of the Watershed Dynamic Model (WDM) (Zi et al., 2021, 2022), future erosion and sediment transport processes in watersheds that drain to the Bay can now be represented and simulated in a dynamic manner reducing the uncertainties associated with a static flow-load relationship and providing more detailed spatial resolution. The model can evaluate the impact of total rainfall changes in the future, as well as the impact of the rainfall pattern changes (i.e., more extreme rainfall events). The refined spatial resolution of the WDM allows for the estimation of watershed-specific loads under future climate conditions, providing sediment supply estimates to specific OLUs. This improved sediment estimate at the OLU scale will form a better basis for baylands sediment management. Modeling changes in suspended sediment flux and sediment delivery for future conditions can help predict the sediment delivery to OLUs and contribute to our understanding of how sediment supply to the baylands would change over time, and how these changes affect our management actions to restore tidal marshes.

Study Objectives and Applicable RMP Management Questions

The study will provide information essential to understanding future suspended sediment loads from local watersheds to selected OLUs, which will support the future development and application of a coupled watershed-Bay model aimed at answering key management questions. The table below shows the objectives of the study and how the information will inform RMP Sediment Workgroup management questions, WRMP questions, and BCDC questions.

Stakeholder Group	**Management Question**	**Study Objective**	**Example Information Application**
RMP - Sediment WG	Foley et al. (2023) - 3. What are the sources, sinks, pathways, and loadings of sediment and sediment-bound contaminants to and within the Bay and subembayments? 3.1 How will watershed load to the Bay change in relation to changing climate, vegetation cover, and land use? 4. How much sediment is passively reaching tidal marshes and restoration projects and how could the amounts be increased by management actions? 4.4 What is the accretion/erosion rate of existing marshes and mudflats and shallow subtidal shoals (locally and regionally) in relation to wave	Predict future sediment load from watershed to selected OLUs. Provide a potential future sediment load range and use that information to guide sediment management.	Produce estimates of suspended sediment loads from local tributaries under a range of future climate conditions. The output of this study specifically addresses the change of watershed load to changing climate in 3.1 and the result can be used to inform 4.1 on the accretion/erosion rate in relation to local sediment supply in 4.1. .

	exposure, local sediment supply and other factors, and how is it expected to change with deeper water and other factors associated with sea level rise?		
WRMP	WRMP (2020) - How are external drivers, such as accelerated sea level rise, development pressure and changes in runoff and sediment supply, impacting tidal wetlands?	Project the changes of sediment load from watershed due to the changes of precipitation and explore how the weather pattern drives the changes of sediment load to wetlands.	Comparisons of sediment loads under different climate scenarios could reveal how sensitive sediment supply is to weather drivers.
BCDC	BCDC (2016) - What do we estimate to be the change in sediment supply/erosion of our watersheds into the future (using modeling)?	Model outputs will supply quantifiable evidence of the changes in sediment supply under different future climates.	Use the WDM model to predict future sediment load from watersheds with different climate change scenarios.

Approach

Task 1 Climate data collection and analysis

We propose to use the downscaled climate projections from the latest generation of climate models from Coupled Model Intercomparison Project Phase 6 (CMIP6) to provide future climate scenarios. Scenarios in CMIP6 are called Shared Scenario Pathways (SSPs) which incorporate socioeconomic factors impacting potential greenhouse gas reduction scenarios. A middle of the road global emissions scenario (SSP2-4.5) and very high global emissions scenario (SSP5-8.5) will be used to represent different future climate projections. The future prediction will be centered on two periods: the mid-Century (2040-2059) and the end-Century (2070-2099). The downscaled modeling results from an ensemble of five climate models (ACCESS-CM2, EC-Earth3, EC-Earth3-Veg, UKESM1-0-LL, HadGEM3-GC31-LL), will be processed to account for the projection variance caused by the differences in climate models. The five climate models were selected based on the GCM skill evaluation results for California's Fifth Climate Change Assessment (Krantz et al. 2021). The bias-corrected downscaled projections from selected climate models will be used to provide boundary conditions for a range of WDM simulations. This task will involve retrieving climate model data (Pierce et al., 2018) and downscaling them to hourly datasets following the procedures used in previous applications of the WDM (Zi et al., 2021, 2022).

Task 2 WDM modeling design and preparation

In this task, the model design will be created. Two OLUs, Alameda OLU and Napa and Sonoma OLU are selected for the modeling study, because of the large sediment contributions from Alameda Creek, Napa River and Sonoma Creek. Alameda Creek watershed is a major sediment calibration watershed of WDM, which has long term sediment load data available and a higher confidence level of WDM prediction than ungauged watersheds. Napa River and Sonoma Creek both have discharge-sediment rating curves developed based on the monitoring data collected from 1950s to 1960s, and provide an opportunity to evaluate changes to rating curves under future climate conditions. Downscaled climate data from two SSPs, two time periods, five different climate models (20 future climate projections for each OLU) will be used to provide forcing conditions for WDM sediment simulation at each of the OLU region. Refined datasets developed in Task 1 will be prepared for input into the WDM using a series of processing scripts developed by the modeling team (Zi et al., 2022). Model inputs for local watersheds (detailed in Zi et al., 2021) will be prepared prior to model implementation.

Task 3 Future sediment load simulation

This task focuses on implementing the WDM using processed data from Tasks 1 and 2, a total of 40 WDM simulations. Each model run will produce sediment load time series from watersheds to the OLUs at an hourly time step that will enable event-scale estimates of future sediment loads from local watersheds to the selected OLUs. Model predicted future sediment loads can be compared to historical runs of the WDM to evaluate the changes of sediment supply in future. The analysis of these model outputs will follow the methods described in Zi et al., 2021 and Zi et al., 2022 and include sediment concentration, load estimation, and projected sediment patterns in relation to projected OLUs sediment demand. Discharge-sediment rating curves under future climate conditions will be derived based on the modeled data and compared with the historical rating curves.

Task 4: Sensitivity analysis of sediment loads in relation to land use and vegetation cover

The changes of future sediment supply are not only subjected to climate change, but also other factors such as land use and vegetation cover changes. Task 1 to 3 are mainly focused on the impact on sediment supply from climate change. Task 4 aims to prepare the model for future improvements by evaluating land use and vegetation cover changes. This task is to prepare future model versions to incorporate dynamic land use and vegetation cover change. To accomplish this, a sensitivity analysis will be performed by varying the values of key land use and vegetation cover parameters and analyzing the changes in sediment loads. This analysis is intended to provide an initial assessment of the importance of these parameters; based on the findings from this task, future model versions could include methods to vary land use dynamically along with weather and climate forcings. This task will produce a comparison of sediment loads driven by climate changes and by land use changes.

Task 5 Report and scientific communication

Results of the study will be presented to the RMP Sediment Workgroup. A discussion of overall uncertainties of this model study will be included. We will also keep the RMP TRC and WRMP Technical Advisory Committee informed of progress. We will provide a project update at the spring 2024 RMP workgroup meeting(s) and plan to share findings at a sediment oriented conference in fall 2024. The final deliverable will be a technical report that is aimed for submission to a peer-reviewed journal by December 2024. The draft report will be provided to the RMP Sediment Workgroup, RMP Sources Pathways and Loadings Workgroup, and TRC for review. The modeling results will be archived to SFEI's server and be available to support future studies from other workgroups and stakeholders.

Budget

The proposed work can be completed in one year with an estimated cost of $82.3K. The expected deliverable is a final report about future sediment loadings predictions for the two OLUs.

Task	Estimated Hours	Estimated Cost
1. Climate data collection and analysis	172	$20,630
2. WDM modeling design and preparation	107	$13,855
3. Future sediment load simulation	100	$13,700
4. Sensitivity analysis	88	$13,720
5: Report and scientific communication	140	$20,420
Total	**607**	**$82,325**

Budget Justification

Labor

This is a desktop analysis, with funding intended to support SFEI staff conducting the data collection and model simulation.

Reporting

The final report will be a technical report that is aimed for submission to a peer-reviewed journal by December 2024. The technical report will be provided to the RMP Sediment Workgroup, Sources Pathways and Loadings Workgroup, and TRC for review. The model results will be archived and available for the public.

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SPLWG Special Study Proposal: Integrated Monitoring and Modeling to Support PCBs and Mercury Watershed Loads Uncertainties Assessment and Monitoring Design

Summary: The Sources, Pathways, and Loadings Workgroup (SPLWG) has done extensive work on the design and implementation of modeling and monitoring techniques to support estimates of stormwater flows, suspended sediment (SS), and contaminant concentrations and loads in the local tributaries that ring the Bay. The RMP has monitored stormwater throughout the region over the last 20+ years, providing the foundational data to support watershed model development. With the recent development of the Watershed Dynamic Model (WDM), flow, suspended sediment, and PCBs and Hg loads from local tributaries can be estimated at an hourly scale. The SPLWG is now building an integrated modeling and monitoring framework to further address the PCBs and Hg management questions, such as the PCB TMDL reconsideration planned for 2028. This proposal is for funding in 2024 and 2025 for the integrated monitoring and modeling activities for PCBs and Hg. In this study, we propose to: continue the second year of a two-year monitoring study to support the PCBs and Hg loads estimation, estimate model uncertainties, determine model sensitivities to parameter and data weaknesses, and provide PCBs and Hg monitoring design recommendations. The outcomes are envisioned to also provide an improved structure as a starting point for monitoring and modeling any future contaminant of interest.

Estimated Cost: $217K for Phase 1 (2024); $167K for Phase 2 (2025); $384K for Phase 1 + Phase 2
Oversight Group: SPLWG
Proposed by: Pedro Avellaneda, Alicia Gilbreath, Tan Zi, and Lester McKee (SFEI)
Time Sensitive: No

Proposed Deliverables and Timeline

Deliverable	Completion Season (Phase 1)	Completion Season (Phase 1 + Phase 2)
Wet season 2024 samples collected and sent for lab analysis	04/2024	04/2024
Laboratory analysis, QA, & Data Management	09/2024	09/2024
Presentations to the SPLWG meeting	05/2024	05/2025
Draft Final Report	-	12/2025
Final Report	-	03/2026

Background

The San Francisco Bay TMDLs call for a 50% reduction in Hg loads by 2028 and a 90% reduction in PCB loads by 2030, respectively. To implement these TMDLs, the Municipal Regional Permit for Stormwater (MRP) (SFRWQCB, 2009; 2015; 2022) called for the implementation of control measures to reduce PCB and Hg loads from urbanized tributaries. The MRP has also identified additional information needs associated with improving understanding of sources, pathways, loads, trends, and management opportunities for contaminants. In response to the MRP requirements and information needs, a set of management questions (MQs; see Table 1) have been used to guide RMP and regional stormwater-related monitoring and modeling activities.

Over the past two decades, the SPLWG and Bay Area Municipal Stormwater Collaborative (BAMSC) have focused on answering MQs 1, 2, and 4 in relation to PCBs and Hg, mainly based on an intensive field-based monitoring approach, and identifying watersheds exhibiting high relative concentrations to help prioritize areas for greater management focus. In recognition of the need to answer MQ3 (How are loads or concentrations of POCs from small tributaries changing on a decadal scale?), starting in 2019, the regional Watershed Dynamic Model (WDM) has so far been developed for hydrology (Phase 1) and sediment (Phase 2) simulation with load modeling of PCBs and Hg (Phase 3) being completed presently. Future applications of the WDM could also be developed to provide a mechanism for evaluating the potential for management actions and management impact on future pollutant loads or concentrations in support of MQ5.

Whereas in the past we have relied on collecting empirical data to estimate loads to the Bay margins and Bay food web, going forward we plan to use an integrated modeling-monitoring approach to address management questions more effectively. Monitoring design driven by modeling needs can lead to more accurate, efficient, and effective modeling, thus improving decision-making. However, the datasets to support a robust model calibration of PCBs and Hg for the Bay Area need improvement. To help verify the WDM load estimation to the Bay from local watersheds over time, a two-year monitoring study was proposed and funded in 2022 to collect load monitoring data (data with both concentration and flow rate) from three watersheds. The monitoring data from these three watersheds will help to fill the data gaps in two ways: PCB samples at Guadalupe River will extend the time series at that location, which will be used to support the temporal aspect of model calibration and explore temporal trends, and samples collected at Arroyo Corte Madera del Presidio and Walnut Creek will fill the spatial calibration weaknesses in the present model. The first year of the monitoring study was approved in summer 2022 and sampling was conducted at the three watersheds during water year (WY) 2023. We propose to continue the second year of load monitoring in WY 2024.

The WDM Phase 3 work - estimating PCBs and Hg loads from local tributaries - will be completed in 2023. However, the WDM is currently calibrated against the loading data of PCBs and Hg from only seven sampled watersheds, representing less than 5% of the modeling domain for PCBs, and less than 0.5% for Hg. Improving the spatial representation with additional data collected in this proposed monitoring task will improve the calibration and decrease the degree of uncertainty. Even with this additional data, however, uncertainty in the PCBs and Hg load estimation will remain. In the case of PCBs, with a reconsideration of the PCBs TMDL planned for 2028, a new robust estimate of PCB load and quantified model uncertainties are needed to link management effort with load reduction progress and to link to the enhanced in-Bay fate modeling that is also being conducted under guidance from the PCB Workgroup. To better assess the uncertainty of PCB load estimation and provide recommendations for monitoring design to reduce uncertainty, a Monte Carlo simulation-based uncertainty study is proposed for 2024. The WDM will also be used to evaluate different monitoring designs. The integrated effort proposed here is a pilot study to use the WDM to guide monitoring design in order to reduce uncertainties of load estimation. The workflow, method and tools we hope to develop in this study for PCBs and Hg can be modified and refined for a broader use in the future.

Study Objectives and Applicable RMP Management Questions

The proposed monitoring effort will provide load monitoring data to fill spatial gaps and to extend existing load monitoring time series. The pilot uncertainty analysis study will quantify the prediction uncertainty associated with PCB and Hg loads estimated by the WDM and evaluate different monitoring designs and parameter sensitivities to answer following questions:

1. What model parameters contribute greatest to model uncertainties?
2. What is the uncertainty of WDM load estimation?
3. What is a suggested monitoring design to reduce uncertainties and support load estimation?

This proposed work is a pilot study to support an integrated monitoring and modeling strategy. The WDM can be used to assess monitoring strategies and quantify how informative they are for load estimation. We anticipate that the workflow, methods, and tools developed in this study can be applied to other contaminants in the future.

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

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

Management Question	Study Objective	Example Information Application
Q1: What are the loads or concentrations of Pollutants of Concern (POCs) from small tributaries to the Bay?	Use paired load sampling to support load estimation. Modeling analysis provides uncertainty estimates of the load predictions from WDM.	The model will produce an estimate of PCBs concentrations and loads at selected watersheds with uncertainty ranges.
Q2: Which are the "high-leverage" small tributaries that contribute or potentially contribute most to Bay impairment by POCs?	Provide modeled load from different tributaries to in-Bay transport and fate model to evaluate the contribution from different tributaries	The model can provide tributary loadings to priority margin units for the in-Bay model to simulate the contaminant transport and fate at those regions.
Q3: How are loads or concentrations of POCs from small tributaries changing on a decadal scale?	Uncertainty analysis of the load estimation will help quantify the possible ranges of load estimation.	Model outputs of PCBs (load and uncertainties) can help us understand the uncertainty of trend estimation.
Q4: Which sources or watershed source areas provide the greatest opportunities for reductions of POCs in urban stormwater runoff?	Understanding uncertainties caused by land-use relevant parameters can help with the source area identification.	The model uncertainty caused by land use relevant parameters can be used to assess the uncertainties of yield simulation from source areas.
Q5: What are the measured and projected impacts of management action(s) on loads or concentrations of POCs from small tributaries, and what management action(s) should be implemented in the region to have the greatest impact?	Understanding uncertainties caused by land-use relevant parameters can help with the management action effectiveness evaluation.	The model uncertainty caused by land use and control measure relevant parameters can be used to assess the uncertainties of management effectiveness simulations.

Approach

Load Monitoring

Site selection and monitoring design were completed in the first year (WY 2023) of this two-year load monitoring study. Using our standard mobilization criteria and discrete sampling methods for load evaluation (collecting one or two samples on the rising limb, one at the peak, and one or two samples on the recession limb of the hydrograph for a total of four to five samples per storm) (Gilbreath et al., 2015), during WY 2023 we collected samples over two storms on Guadalupe River and Walnut Creek, and during three storms on Arroyo Corte Madera del Presidio. WY 2023 was very wet and we were able to sample sizable storms at each location. Arroyo Corte Madera del Presidio was also sampled during the first of the season flush. We propose to continue load monitoring at the three selected watersheds (Guadalupe River, Walnut Creek, and Arroyo Corte Madera del Presidio) in WY 2024 such that we will complete the two-year study with four to five storms sampled per location with 16-25 discrete samples at each. Data with this level of detail can be used to explain the physics of local rainfall-runoff based sediment transport and contaminant buildup and washoff processes, and verify the representations of those processes in the WDM.

Samples will be collected during rainfall events that are forecast to exceed 0.5 inches of rainfall in a 6-hour period. A minimum rainfall of 0.5 inches represents the best compromise between active pollutant transport processes and the avoidance of false starts - when a field team is deployed but fails to sample due to the lack of rainfall. Discrete samples will be collected using either a D-95 suspended using a crane and winch assembly (larger channels) or an ISCO pumping sampler (smaller channels) following clean hands procedures using appropriately prepared and calibrated sampling equipment.

Water samples will be analyzed for PCBs, Hg, and SSC. SGS AXYS Analytical will analyze for PCBs, Brooks Applied Laboratories will analyze for Hg, and SFEI will analyze the water samples for SSC. We have long experience working with these laboratories and expect the data to be high quality.

Load Modeling Uncertainty Analysis

The Watershed Dynamic Model (WDM) has been calibrated using monitoring data at several locations around the region; however, uncertainties of model predictions such as streamflow and suspended sediment load (SSL) are unavoidable. This uncertainty is due to lack of process representation, poor initial boundary conditions, measurement errors, uncertainties in parameter choices, and, as mentioned above, the limited nature of the calibration data. Estimating uncertainty in the WDM is an important step in assessing the reliability of model predictions and making informed decisions based on model results. There are three key stakeholder questions that need to be resolved. We will perform the analysis in two phases.

1. What model parameters contribute greatest to model uncertainties?

As a first step in the overall uncertainty analysis, we will identify key model parameters that influence the variation of pollutant loads. The initial pool of key model parameters will include parameters related to streamflow and sediment, PCBs, and Hg transport. A model parameter can be allowed to change within a predetermined range (e.g., ±10% of a default value) and the predicted model output summarized by keeping the other parameters fixed. For example, a 10% chance can be applied to the initial pool of key model parameters. If a 10% change in a parameter value generates a 5% change (or higher) in the pollutant load, then that parameter will be kept for uncertainty quantification. By repeating the process with other model parameters, we will identify the influence of individual parameters on model output and create a prioritized parameter list for uncertainty quantification.

2. What is the uncertainty of WDM load estimation? Having a quantitative understanding of uncertainty (±A%) and a qualitative understanding of potential biases (high, low) will improve confidence in the load estimates for decision-making.

We propose to quantify the uncertainty of WDM load estimation by using a Monte Carlo (MC) based method. For example, two widely applied methods are the Generalized Likelihood

Uncertainty Estimation (GLUE; Baven and Binley, 2014) and the Approximate Bayesian Computation (Sadegh and Vrugt, 2014). Within the GLUE framework, we will select a likelihood measure to reflect the agreement between the simulated and observed pollutant loads. Also, we will choose uniform prior probability distributions for the model parameters. Using these distributions, a large number of parameter sets (e.g.,10,000) will be drawn to perform the simulations. A parameter set will be considered acceptable if the likelihood function is above a predefined threshold that represents the agreement between the simulated and observed pollutant loads. The acceptable parameter sets will represent a plausible range of model uncertainty.

With the prioritized parameter list for uncertainty quantification, the Monte Carlo method will deliver a subset of model simulations (e.g., time series for SSC, PCBs, and Hg) that are deemed to be consistent with the observed data. The WDM currently has seven sub-regions. We propose to apply the Monte Carlo simulation method to test one sub-region of the WDM with the best water quality data availability . The subset of model simulations will allow us to estimate pollutant loads and provide an estimate of load uncertainty (±A%). Data weaknesses and how they might contribute to low or high bias will be discussed qualitatively.

3. What is a suggested monitoring design to reduce uncertainties and support load estimation? A key outcome of an integrated modeling-monitoring approach to answering management questions is cost efficiency. How does this coupled approach lead to lower longer term costs and more nimble answers to pressing management questions?

There are three sub-questions that will help us answer this key stakeholder question: 1) Did adding additional monitoring on Guadalupe in 2023 and 2024 improve the model calibration for trends through time? 2) Did adding two additional watersheds improve the spatial calibration? 3) In hindsight, even if uncertainties are greater, would similar loads be predicted using fewer watersheds for calibration with fewer water years of data? We will produce two model outputs: 1) estimated pollutant loads considering *only* hydrologic forcing (e.g., rainfall, evapotranspiration) for the WYs 2023 and 2024, and 2) estimated pollutant loads considering the hydrology and water samples collected during WYs 2023 and 2024 which were intended to help improve the temporal and spatial aspects of the model. These two model outputs will allow us to detect differences in estimated pollutant loads (and their range of variation) with and without the additional two-year load monitoring effort. Based on these numerical experiments, we will make recommendations for future monitoring design.

Contaminants of Emerging Concern (CEC) can adsorb onto sediment particles through physical and chemical interactions. Once adsorbed, CEC can persist in sediments for long periods of time with potential for release back into the water column. Since the WDM can simulate sediment loads associated with surface runoff, we anticipate that the uncertainty analysis work can be applied to the simulation of sediment-associated CECs.

The tasks for the uncertainty analysis include:

Phase 1:

1. WDM modification

Currently, a user of the WDM populates model parameters via its graphical user interface. The source code of the WDM will need to be adapted to facilitate integration with a Monte Carlo based calibration technique. We propose to modify the source code to allow automation of the Monte Carlo simulation process.

2. Uncertainty method and tool development

We propose to identify an appropriate method for uncertainty quantification and develop a tool to integrate the WDM and the uncertainty quantification method.

Phase 2:

3. Parameter sensitivity analysis

A sensitivity analysis will be conducted on key modeling parameters to help us identify priority parameters as major contributors to model uncertainties.

4. Pilot uncertainty quantification

The uncertainty quantification will be applied to a test sub-region of the WDM using a priority parameter list identified in task 3.

5. Model performance evaluation using data from the two year (2023 and 2024) load monitoring campaign

The WDM will produce output (e.g., time series for SSL, PCBs, and Hg) with and without considering monitoring data from the two year load monitoring activities. We will test for any changes in the estimated pollutant loads, and range of variation, due to the newly available dataset.

6. Regional uncertainty quantification

We will apply the uncertainty quantification method to regions not considered in Phase 1.

Budget

The following budget represents estimated costs for this special study (Table 2).

Table 2. Proposed budget cost estimates.

	Phase 1 (2024)		Phase 2 (2025)		Phase 1 + Phase 2	
Expense	**Hours**	**Cost ($)**	**Hours**	**Cost ($)**	**Hours**	**Cost ($)**
Uncertainty analysis	400	$62,000	740	$103,600	1140	$165,600
Stormwater monitoring and data management	484	$71,820			484	$71,820
Report and scientific communication	98	$15,190	279	$43,870	377	$59,060
Project management and science overview	100	$22,134	80	$17,707	180	$39,841
Subcontracts						
SGS AXYS Analytical, Brooks Applied Laboratories		$37,000				$37,000
Direct Costs						
Equipment		$2,050				$2,050
Travel		$2,100		$2,100		$4,200
Shipping		$4,500				$4,500
Total	***1082***	***$216,794***	***1099***	***$166,677***	***2181***	***$384,071***

Budget Justification

Labor Costs: Labor costs include staff time for monitoring and modeling efforts. It will support staff time to conduct fieldwork and data management, develop WDM uncertainty analysis tool, perform calibration/verification, process model results, and write up technical reports; and get technical support from related other parties; and senior staff contributions and review.

Laboratory Costs: Up to 30 independent samples will be analyzed each year, including field duplicates and field blanks. Analyses will be conducted for PCBs, mercury, and suspended sediment concentration.

Data Management Costs: Data services will include quality assurance and upload to CEDEN.

Reporting Costs: Preparation of draft and final reports on the results will be completed.

Reporting

- Presentations at SPLWG meeting
- Final report
- Monitoring data will be made available for the public via CEDEN.
- Model simulation results will be archived in the SFEI server and available upon request.

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SPLWG Special Study Proposal: Tidal Area Remote Sampler Pilot - Year 2

Summary

Old industrial land use disproportionately supplies PCB and Hg mass loads to the Bay. The Municipal Regional Stormwater Permit (MRP) calls for controlling these discharges and a lot of effort has already occurred in non-tidal industrial watersheds, but knowledge about sources and source areas in tidally-influenced areas remains limited due to the challenges associated with sampling in tidal areas. Last year a new remote sampler that addressed these challenges was developed to sample the tidally-influenced industrial landscape. Two samplers were built that automatically collect stormwater samples when freshwater storm runoff is detected. The samplers were deployed at three tidally influenced sites to assess for performance and test alternative methods for physically securing the sampler, but no sampling for lab analysis was completed. In the proposed study, field staff will deploy the equipment at eight sites to capture water samples for PCB and Hg analysis. This study will solidify our experience and understanding on the field deployment of these samplers. The outcome will be a completed and proven sampler design and characterization of stormwater from eight old industrial areas influenced by tides. The deliverable of this project will be quality-assured PCB and Hg data made available through the CD3 web tool, and a report detailing the methods and results of the pilot study.

Estimated Cost: $107k; Carry over from 2023: $45k; Total Requested for 2024: $62k
Oversight Group: STLS/SPLWG
Proposed by: A Gilbreath, D Yee, and L McKee (SFEI)
Time Sensitive: No

Proposed Deliverables and Timeline

Deliverable	Due Date
Pilot testing during rainy season	04/2024
Update presentation at SPLWG on the results to date	05/2024
Data upload to CEDEN	12/2024
Draft Report	1/2025
Final Report	3/2025

Background

Old industrial land use is the main source of the greatest yields and total mass of PCB loads in the region (Wu et al., 2017), but at this time due to sampling logistics, only the non-tidal portions have been well-sampled (Gilbreath and McKee, 2022). Most of the Bay Area's heavy industrial areas, historically serviced by rail and ship-based transport, are located in close proximity to the shoreline. To date, the RMP has sampled stormwater from nearly 100 watersheds and drainages in the region. However, sampling for PCBs and HgT since WY 2003 has included just 34% of the old industrial land use in the region. Of the *remaining* older industrial land use yet to be sampled across all the counties, 48% of it lies within 1 km and 74% within 2 km of the Bay. These areas are more likely to be tidally influenced, and are often not well serviced by public roads.

Tidal areas are very difficult to sample because of a lack of public right-of-ways and a range of tidal-related constraints near the Bay such as bidirectional flow, the timing of tides with storms, the need for boat access to outfalls to install equipment and take samples, complex mixing, and water column stratification. With great patience and effort, some sampling in tidally influenced areas has occurred during the last seven years. To be able to sample these areas, tides that are sufficiently low (site-dependent) must align with storms of sufficient intensity. Additionally, to warrant mobilization for these events to the exclusion of other sampling in the region, these conditions need to be met for some minimum time period (e.g. minimally 2-3 hours) to account for potentially shifting storm timing. Tidal sites get the highest priority during each storm event in which these requirements are met, and yet such opportunities have been rare. Further, we only have so much field capacity to sample each event, so we are limited in the number of tidal sites we can sample when these conditions occur. For several years, the Pollutants of Concern (POC) reconnaissance report stated: "A different sampling strategy may be required to effectively assess what pollution might be associated with these areas and to better identify sources for potential management" (Gilbreath and McKee, 2022).

In response to this challenge, two RMP projects funded the development and early pilot testing of a remote sampler in WY 2023. The EPA had developed a remote, micro-pump sampler and successfully used it over 100 times (Kahl et al., 2014). This formed the prototype from which SFEI developed a modified variant in WY 2023. USGS is currently working on modifications to the EPA design as well, and SFEI benefitted from discussions with USGS about sampler development. This modified variant, the "SFEI Mayfly," is suitable for both CECs sampling in non-tidal pipes and storm drains further upstream, as well as for sampling in tidal areas. The sampler is a compact, automated micro-pump sampler such that staff need not be present during sampling, and can be deployed and retrieved during lower tides prior to and after a storm. Although the samplers may be inundated at times with tidal waters, a salinity sensor triggers the sampler only during low salinity periods when urban stormwater is dominant. The data logger on the sampler is also telemetered such that remote access to real-time data is available over the internet. It is currently not enabled to program remotely, though this would be a highly beneficial feature for a variety of reasons and has been proposed as part of the remote sampler proposal.

Last year, in addition to developing the samplers, we deployed them during storm events at three tidal locations (as well as two non-tidal locations), all of which were mostly successful. These were pilot testing locations to assess the feasibility of field deployment only. No samples were submitted for analysis as these were not locations where information on PCBs or Hg was desired. Some lessons were learned in this pilot phase that will be applied in future sampling. The sampler was in development most of the rainy season and we only began field deployments towards the end of the season, therefore we were not able to collect samples desirable for lab analysis. There is approximately $45,000 in remaining funds for the project, and we propose to carry that over into this year and thus lessen the cost of the proposed project by that same amount (see Budget Table 2).

In this study, we propose to deploy these samplers for collection of Hg and PCBs and data analysis at eight locations. This study will solidify our experience and understanding on the field deployment of these samplers, and identify industrialized or other urban drainage areas on the Bay margin for further investigation and management consideration, thus providing a much-needed new tool for stormwater managers.

Study Objectives and Applicable RMP Management Questions

The goal of this project is to further modify and deploy a remote sampler for sampling in tidal areas.

The near-term objectives of the sampling approach will be to (a) deploy the sampler at eight sites, and (b) collect PCBs, Hg, and SSC samples at each site and have these samples analyzed by commercial labs.

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

Management Question	Study Objective	Example Information Application
Q1: What are the loads or concentrations of Pollutants of Concern (POCs) from small tributaries to the Bay?	Deploy a remote sampler to collect POC data in tidal areas that we have previously been unable to sample due to tidal constraints.	What are the concentrations of POCs downstream of industrialized areas close to the Bay margin?
Q2: Which are the “high-leverage” small tributaries that contribute or potentially contribute most to Bay impairment by POCs?	Indirect, via answering Q1	Identify high leverage drainages to sensitive Bay margins downstream of tidally influenced industrial areas.

Management Question	Study Objective	Example Information Application
Q3: How are loads or concentrations of POCs from small tributaries changing on a decadal scale?	N/A	N/A
Q4: Which sources or watershed source areas provide the greatest opportunities for reductions of POCs in urban stormwater runoff?	Indirect, via answering Q1	Confirm/refute if high PCB concentrations are found downstream of suspected PCB source areas.
Q5: What are the measured and projected impacts of management action(s) on loads or concentrations of POCs from small tributaries, and what management action(s) should be implemented in the region to have the greatest impact?	N/A	N/A

Approach

Our approach during this second year of work with the SFEI Mayfly is to deploy the samplers at eight locations where PCB measurements are desired. The intent is to deploy the two sampling units that are currently built at two different locations during four storm events for a total of eight locations.

In this study, we will work with the BAMSC team to select suitable and desirable locations for deployment. We will either access sites by land or utilize a low draft boat or other means to access tidal sites downstream from old industrial areas. There we would anchor the coarse-screened micro-pump sampler and an auto-logging micro salinity probe in the water column. The sampling equipment would be installed just prior to a storm and retrieved after. The whole water sample would be analyzed for suspended sediment, PCB, and Hg concentrations.

Budget

The following budget represents estimated costs for this special study (Table 2).

Table 2. Proposed budget.

Expense	Estimated hours	Estimated Cost
Labor		
Field Deployments	168	$33,840
Project Management	60	$9,712
Data Management	90	$12,600
Reporting - SOP Development and Report	156	$30,480
Subcontracts		
SGS AXYS Analytical, Brooks Applied Laboratories, USGS		$12,065
Direct Costs		
Equipment		$6,000
Travel		$330
Shipping		$1,800
Grand Total for WY 2024	474	**$106,827**
Total Remaining for WY 2023		**$44,800**
Total Requested for WY 2024		**$62,027**

Budget Justification
Labor Costs: 574 hours of staff time to research and modify the remote sampler, deploy the sampler, analyze the data, and present to SPLWG in spring 2024.

Early Funds Release Request
If this project is approved, we request early release of funds for use in 2023. We would begin modifying the remote sampler in fall of 2023 such that we are ready for deployments in Water Year 2024 (which begins fall of 2023).

Reporting

The data for the remote sampler will be presented to SPLWG in the spring of 2024. Additionally all data will be uploaded to CEDEN and a technical report (draft and final) will detail the methods and a brief presentation of the results. Further, a detailed Standard Operating Procedure document will be created to describe the sampler development and operation.

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SPLWG Special Study Proposal: Using a Detection Dog Team for Source Tracing of PCBs

Summary

This study will be an important step towards assessing the feasibility of incorporating PCB detection dogs into routine practice to help facilitate PCB source tracing efforts in the Bay Area. FieldLab LLC (Julianne Ubigau and her trained detection dog) has already proven its PCB detection capabilities in two pilot studies in Seattle, WA, plus source tracing in Seattle and Spokane. In this proposed study, SFEI staff will collaborate with various partners to gather the necessary information to help determine if canine PCB detection is a viable and efficient tool to incorporate into Bay Area source tracing efforts, and provide the background material necessary for developing a proposal for future implementation funding. Working closely with the Water Board and BAMSC to ensure the data are relevant to their needs, we will discuss sample types, desirable survey types, prudent land use categories, and PCB analytical methods. Next, SFEI will work with Julianne Ubigau to establish the costs and pace of the Water Board and BAMSC's previously determined preferences and assess the scalability of the canine method. Finally, we will work with BAMSC to evaluate available information regarding the potential cost-effectiveness of integrating this new tool into the existing Bay Area efforts to identify properties that are sources of PCBs to stormwater discharges. The combination of these collaborative efforts will allow us to determine if using detection dogs in PCB source tracing efforts in the Bay Area is potentially resource-efficient. The final report for this proposed project will provide recommendations for next steps in the Bay Areas with the canine PCB detection method as appropriate (e.g., pilot testing or early implementation), and be a valuable resource to developing a larger proposal in the future.

Estimated Cost: $25k
Oversight Group: SPLWG, PCBWG
Proposed by: A Gilbreath, J Dougherty (SFEI)

Proposed Deliverables and Timeline

Deliverable	Due Date
Project planning in consultation with Water Board, BAMSC - Task 1	11/30/2023
BAMSC partnerships, survey areas, sample types & prior PCB costs - Task 2	2/28/2024
Define scenarios with FieldLab LLC - Task 3	2/28/2024
Presentations to Water Board, BAMSC, PCBWG, and SPLWG	5/31/2024
Draft Report	3/31/2024
Final Report	6/30/2024

Background

Through many efforts by the Permittees, the Water Board, EPA, and DTSC, many major PCB source properties have been identified for cleanup throughout the Bay Area. However, finding additional sources remains an important yet challenging endeavor. Primarily led by BAMSC and supported by SFEI, multiple methods have been employed to try to trace sources in the landscape. Yet these methods are resource intensive, slow to progress, and have significant limitations. As an example demonstration of these efforts, below is a closer look at one area of particular concern and the work that has been accomplished to date.

The partially-enclosed San Leandro Bay (SLB) and its margins have been identified as a high priority for management and monitoring based on observations of high concentrations of PCBs in water, sediment, and biota and the potential for interventions to reduce loads in the adjoining watersheds. Although two major sources of PCBs have been identified in the SLB PMU watershed (including a former General Electric (GE) property and a former Union Pacific Railroad (UPRR) site), finding more properties and areas for cleanup is difficult. Typically, in the Bay Area, when we find high concentrations of PCBs, e.g. in street dirt or drop inlets or on properties, it is within an older industrial area. Whereas the region has approximately 3% of old industrial area, the SLB watershed has 8.5% or 7 sq km of old industrial area. Figure 1 shows the watershed area (outlined in red) draining to the SLB and the significant area of old industrial land use (shaded in darker gray and located primarily closer to the Bay).

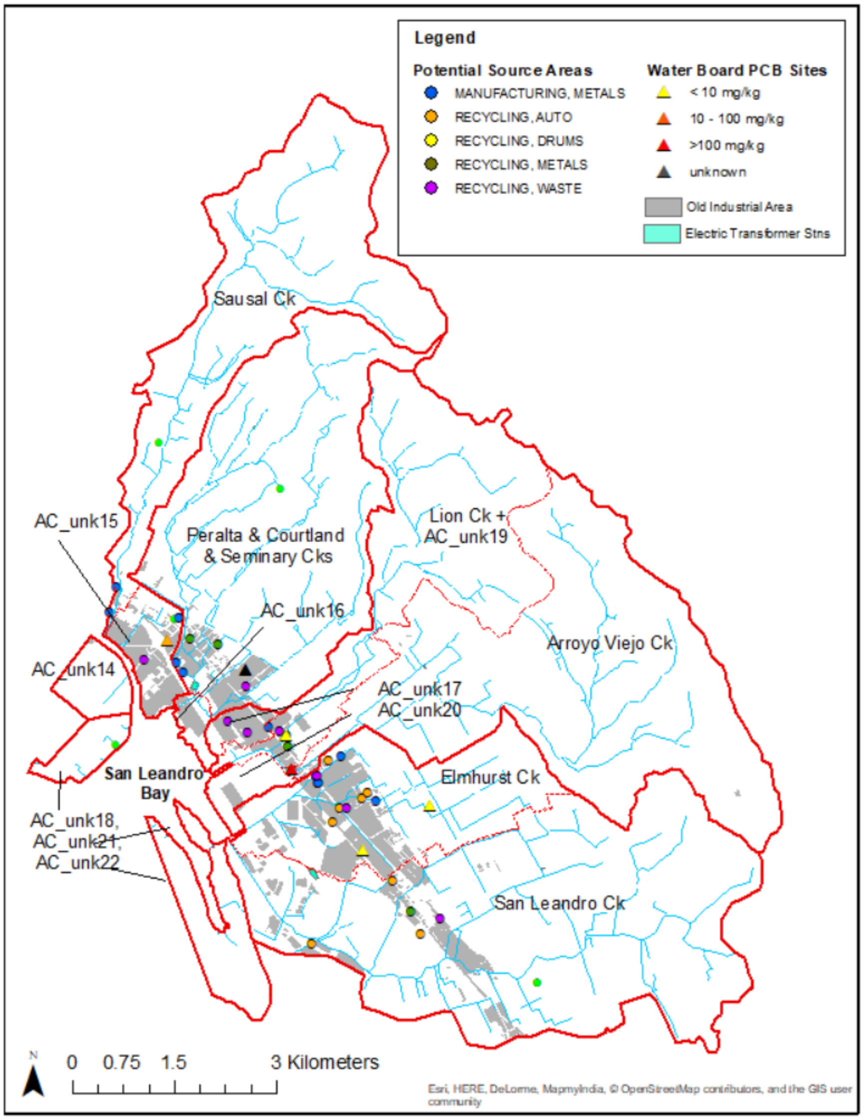

Figure 1. San Leandro Bay (SLB) and its watershed (outlined in red). The old industrial area, potential source areas, and properties identified by the Water Board as having high PCBs are included.

However, not all old industrial areas have high concentrations of PCBs, and the areas must be investigated. One method of investigation is to collect soil and sediment samples from creeks, streets, and drop inlets in the watershed. Such samples are typically considered moderately contaminated at concentrations of 200 ug/kg, and samples greater than 1000 ug/kg are typically considered a source. To date, 55 PCB soil and sediment samples have been collected in the San Leandro Bay watershed (Figure 2). Many of these sampling locations were selected specifically because it was believed that they may have higher concentrations of PCBs. A substantial amount of resources went into identifying these sampling locations, collecting the samples, paying for lab analysis, and then analyzing the data, yet of the 55 samples, approximately half had concentrations that were below 50 ug/kg and <20% had concentrations above 200 ug/kg.

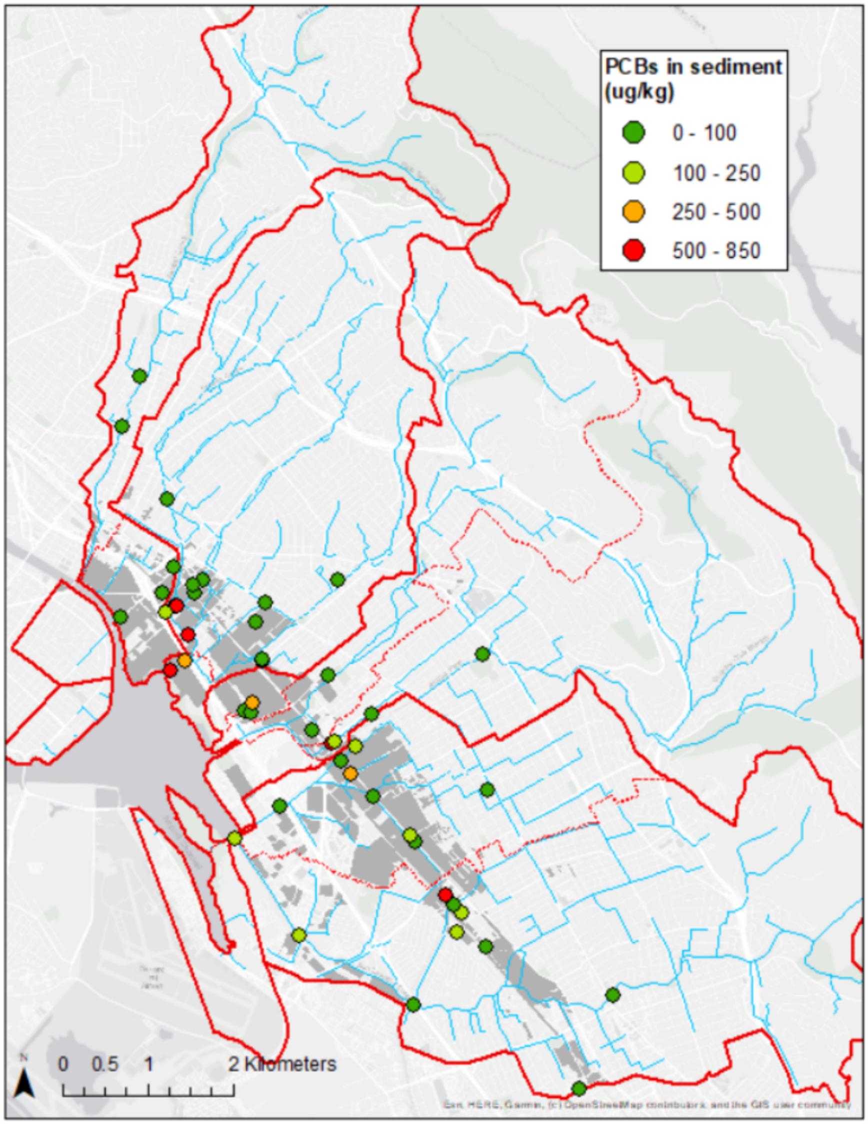

Figure 2. Sediment and soil sample data collected in the SLB watershed.

As an alternative tool for identifying contaminated areas, we can use stormwater monitoring to try to identify subwatersheds that are elevated in PCBs, and then use that information to go upstream in the watershed to try to find sources. The stormwater monitoring data also may help to identify large areas that are not of particular interest. While this is an important tool, it is extremely challenging to sample downstream of much of the old industrial area because it lies within areas that are tidally influenced by the Bay. This is evident in Figure 3, where the subwatersheds (shaded light blue) have been sampled for stormwater at locations as far down in the watershed as feasible. Much effort went into collecting these samples that were primarily slightly below the tidal interface, and still, we were unable to sample below approximately half of the old industrial area in the SLB watershed.

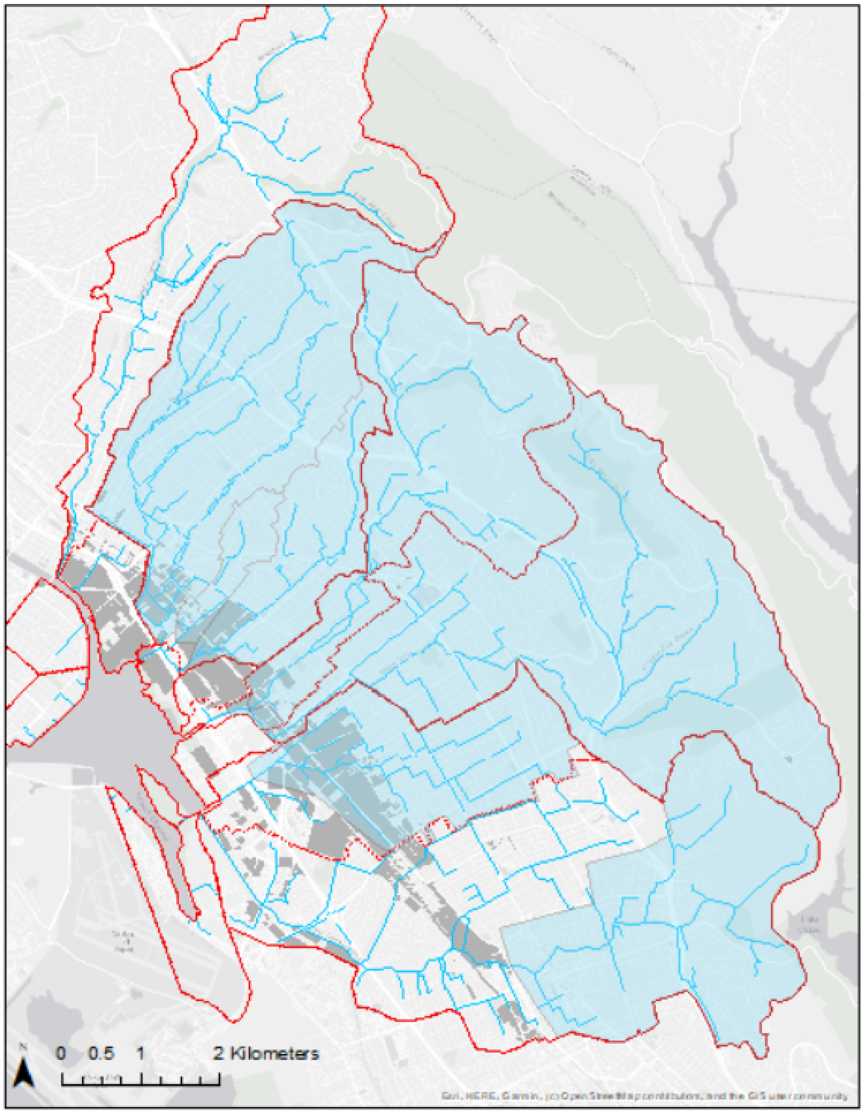

Figure 3. Blue-shaded areas represent the subwatersheds of the SLB watershed where storm sampling has occurred. As in previous figures, the old industrial area is shown in darker gray.

This is a closer look at just one example area around the Bay where extensive work has been done to identify PCB sources, and it highlights the need for finding or developing new tools for PCB source identification.

RMP stakeholders have recently identified a new method to more efficiently hone in on locations with elevated PCB concentrations in the watershed, and improve on both challenges of being able to search below the tidal interface as well as improve the rate at which we measure high concentrations in soil and caulk samples. A PCB detection method using scent-detection dogs was pioneered in 2016 by FieldLab LCC (Julianne Ubigau and her canine cohort, Sampson) as part of a collaborative project between the University of Washington (UW), Seattle Public Utilities (SPU), and the Washington Department of Ecology. Sampson has been trained on more than 20 targets including PCBs.

During the pilot project, dog training was phased. In phase one the dog was exposed to various materials spiked with Aroclor 1254 or 1260 using three different types of placement; in benches, under screens, and within walls. In phase two, these spiked materials as well as archived samples from SPU were placed in field sites in natural and industrial areas that were free of PCBs to allow the dog to locate placed samples in more realistic scenarios and varying conditions. Controlled testing was performed to determine if Sampson could consistently detect PCBs in various placed media, and to move forward with more realistic training and testing. Sampson correctly alerted in 98% of bench tests, with no false alerts (Windward Environmental LLC, 2017). During testing for phase two which included six trials with 14 total placed samples, Sampson alerted 92% of PCB samples and did not alert for the blanks (Windward Environmental LLC, 2017). Materials for training and testing included; caulk, paint chips, catch basin solids, street dirt, forest soil, clean sand, a milk crate, an electronics recycler, transformer fluid, coolers, cotton, and wood. Phase three was carried out at sites known to have PCB contamination, so the dog was detecting PCBs in the field. Testing of phase three occurred at 17 industrial sites. In this phase, the dog responses were categorized into none, low, low-moderate, moderate, and strong. These tests provided a sense of Sampson's ability to detect various concentrations of PCBs in field testing environments. Strong responses ranged from 1.17 to 164,100 mg/kg, while moderate ranged from 0.023 to 2.65 mg/kg (Windward Environmental LLC, 2017).

Although Sampson was the only detection dog trained for PCB detection as part of the 2016 pilot study, the handlers learned lessons from the study that improved their ability to train future dogs for PCB detection. The project determined the ability of dogs to reliably detect PCBs at levels as low as 0.1 mg/kg. More importantly, the pilot project demonstrated a clear potential for canines to become a powerful new tool that can streamline PCB source tracing efforts. For example, at one site, Sampson quickly identified a hotspot in soil (63.81 μg/kg) that would not have been found by SPU investigators without extensive investigation and sampling (Windward Environmental LLC, 2017). Additionally, Sampson allowed for a 57% decrease in sample collection, when compared with 2014 source tracing efforts (Bidwell et al., 2021). They concluded that using the dog PCB-detection team resulted in highly efficient searchability. The team was able to quickly and effectively screen large areas on industrial sites for PCBs and was successful at both finding sources of PCBs and showing a lack of interest in their absence. Therefore, dog detection can be helpful in three critical scenarios; suspected PCB property area search, broad area search, or drainage system mapping. Additional considerations include: ensuring temperatures are between 45°F and 80°F, winds less than 10 miles per hour, and awareness of potential distractions to the canine (Seattle Public Utilities, 2023). Today, FieldLab, UW, and SPU continue to work together with a shared mission to optimize pollution source control efforts and help others learn about how they can integrate this new tool into their current management practices.

Jasper is the current detection dog that works with Julianne for identifying PCBs. Jasper and Julianne completed a field survey for SPU in August 2021 in which Jasper identified PCB sites in Spokane including; building exteriors, dry wells, doorways, stormwater drains, gravel banks, water, cinder blocks, and perimeters (Ubigau, 2021). In total over three survey days, Jasper identified 19 sites of interest, including 9 of high interest, six of medium interest, and four of low interest. The team concluded that the source of PCBs was likely from buildings and contaminated soil within the stormwater drainage discharging to a particular outfall and that field testing at those sites should be the next step in the process.

Although FieldLab's previously successful work in Washington suggests that this method could be a promising new tool for use in the Bay Area, important questions remain before piloting this work and/or considering implementation on a larger scale. In this proposed RMP study, we will work with FieldLab and stakeholders in the Bay Area to develop the groundwork for planning source tracing efforts using a scent detection dog team in this region.

Study Objectives and Applicable RMP Management Questions

The goal of this project is to determine the cost-effectiveness and scalability of incorporating detection dogs into routine practice to help facilitate PCB source tracing efforts in the Bay Area.

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

Management Question	Study Objective	Example Information Application
Q1: What are the loads or concentrations of Pollutants of Concern (POCs) from small tributaries to the Bay?	N/A	N/A
Q2: Which are the "high-leverage" small tributaries that contribute or potentially contribute most to Bay impairment by POCs?	N/A	N/A
Q3: How are loads or concentrations of POCs from small tributaries changing on a decadal scale?	N/A	N/A
Q4: Which sources or watershed source areas provide the greatest opportunities for reductions of POCs in urban stormwater runoff?	Develop the planning information necessary to complete source tracing efforts for PCBs via the use of scent detection dogs.	Identify areas and properties with elevated PCBs for management action.

Q5: What are the measured and projected impacts of management action(s) on loads or concentrations of POCs from small tributaries, and what management action(s) should be implemented in the region to have the greatest impact?	Indirect, via answering Q4	By identifying locations/areas with high PCBs, we can start to formulate the most effective management action plans to treat or intercept those PCBs from getting to the Bay.

Approach

A canine PCB detection method was piloted in Seattle, WA from 2016-2022, and it continues to be used there for source tracing efforts. This proposed project involves a collaboration with local stakeholders and FieldLab LLC to develop the background materials necessary to better define how this tool can be used here in the San Francisco Bay Area, for estimating the cost-effectiveness of integrating this tool into regular source tracing efforts, to better understand the scalability of this tool to a larger region, and to serve as the starting point for developing a more robust implementation proposal. These goals will be achieved by following the approach described in the three tasks below.

Task 1: This task involves building consensus on beneficial types of data to collect, making implementation in the future straightforward. SFEI will collaborate with the Water Board and BAMSC to determine which PCB analysis method best supports the needs of the Permittees and the Municipal Regional Stormwater Permit. Aroclor methods are much less expensive than congener methods, though they have higher reporting limits and the trade-offs between these methods should be revisited. Here, stakeholders will weigh in on the reporting levels and granularity of data needed to select an appropriate analytical method for PCB analysis. Additionally, SFEI and stakeholders will define the sample types most worthwhile to stakeholders (sediment, soil, caulking, etc.), preferable land use categories (e.g., old industrial, business parks, areas of older commercial and transportation) and advantageous survey types (broad area searches to cover a lot of ground, property area searches focused on pinpointing sources on a property, storm drain inlet or outfall searching to identify catchments of interest, etc.). How to best handle the complexities of working with property owners will also be discussed though there is currently no clear way to compel property owners to allow sampling.

Task 2: Work closely with Julianne Ubigau of FieldLab LLC to constrain the costs and pace for the scenarios and conditions identified in Task 1. We will carefully define the project process from start to finish of working with FieldLab. Determine the scalability of the canine method by considering requirements to train new dogs and handlers, and the time that FieldLab would be able to commit to working within our region each year.

Task 3: Determine the predicted cost-effectiveness using a BAMSC-suggested metric. We will compare previous methods for PCB detection (sediment/soil sampling at suspected areas of contamination, stormwater monitoring) and the expected outcomes from Task 2 using the canine method. Compile the information from previous tasks to determine if detection dogs are efficient to incorporate into routine practice to help facilitate PCB source tracing efforts in the Bay Area. The final report for this proposed project will allow for the streamlined implementation of the canine PCB detection method as appropriate. In addition to an RMP technical report (draft and final), SFEI will present the findings to stakeholders at SPLWG and PCBWG in the spring of 2024.

Budget

The following budget represents the estimated costs for this study (Table 2).

Table 2. Proposed budget.

Expense	**Estimated hours**	**Estimated Cost**
Labor		
Project Management, Planning & Collaboration	94	$14100
Reporting and Presentations	52	$7800
Subcontracts		
Field Lab LLC (Julianne Ubigau)		$3,000
Grand Total	146	**$24,900**

<u>Budget Justification</u>
Labor Costs: 146 hours of staff time to collaborate on defining the project, manage the project, present to interested parties including the SPLWG in the spring of 2024, and finalize a report.

Reporting

Details of the analysis will be documented in an RMP technical report. Presentations of the method and results will be delivered to stakeholders at SPLWG and PCBWG.

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SPLWG/ECWG Proposal: Remote Sampler Purchase

Summary

This proposal will fund the purchase of a set of remote samplers for RMP stormwater work to support stormwater CECs monitoring in Bay Area watersheds and urban runoff monitoring in tidal zones (e.g., to measure PCBs in runoff from industrial areas that flows to tidal waters). These samplers have other potential uses, such as for future urban stormwater microplastic monitoring.

As part of an ongoing project, the 2023 “Stormwater CECs Monitoring Groundwork,” RMP scientists have developed a new small, flexible, relatively low-cost remote sampler (the “SFEI Mayfly”) and are testing and comparing it to the traditional ISCO sampler. Both have already proven their feasibility for field deployment in Bay Area creeks. We have conducted and are currently awaiting results of QA/QC testing of side-by-side blank samples from both samplers. We also await the result of container adherence tests of the flexible containers preferred for use with the SFEI Mayfly. These chemical analysis data for four CECs families of interest to the RMP will inform assessment of the usability of these remote samplers for RMP stormwater CEC monitoring.

This proposal is a placeholder because the analytical laboratory data necessary to support the remote sampler selection will not be available until summer 2023. The sampler selection is anticipated to be made this summer, in consultation with the Stormwater CECs Stakeholder-Science Advisor Team (SST). Upon the sampler selection decision, the sampler purchase/construction task will be developed under the oversight of the SST and brought to the Steering Committee for approval to ensure sampler availability to pilot implementation of the new Stormwater CECs Monitoring Approach in wet season 2023/2024.

Estimated Cost:	$180,000 (early release of RMP funds requested)
Oversight Group:	SPLWG and ECWG, Stormwater CECs Stakeholder-Science Advisor Team
Proposed by:	Kelly Moran, Alicia Gilbreath, and Don Yee
Time Sensitive:	Yes because it supports implementation of the Stormwater CECs monitoring program in wet season 2023/2024.

PROPOSED DELIVERABLES AND TIMELINE

Deliverable	**Due Date**
Task 1. Develop scope and budget for remote sampler purchase	Summer 2023
Task 2. Remote sampler purchase/construction (deliverables to be determined)	Fall 2023-Spring 2024

Background

The RMP transition to a primary focus on CECs monitoring heightens the need to develop a practical, cost-effective method for remotely collecting stormwater samples. Remote sampler capabilities reduce collection costs and make it possible to obtain many more samples per storm event than is possible with current manual sampling techniques. Having this capacity will shorten the time frame necessary to address management questions requiring stormwater monitoring data and will provide new capacities, such as to monitor in difficult to access tidal zones.

Study Objectives and Applicable RMP Management Questions

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

Management Question	Study Objective	Example Information Application
1) What are the loads or concentrations of pollutants of concern from small tributaries to the Bay?	Indirect through building sampling capacity with the remote samplers.	Implementing monitoring projects to address near-term priority stormwater CECs management questions.
2) Which are the “high-leverage” small tributaries that contribute or potentially contribute most to Bay impairment by pollutants of concern	Indirect through building sampling capacity with the remote samplers.	Identification of tributaries with elevated PCBs that drain into margins of concern such as San Leandro Bay.
3) How are loads or concentrations of pollutants of concern from small tributaries changing on a decadal scale?	Indirect through building sampling capacity with the remote samplers.	Understanding the changes in presence of CECs in the stormwater pathway.
4) Which sources or watershed source areas provide the greatest opportunities for reductions of pollutants of concern in urban stormwater runoff?	Indirect through building sampling capacity with the remote samplers.	Identification of tributaries with elevated PCBs.
5) What are the measured and projected impacts of management action(s) on loads or concentrations of pollutants of concern from the small tributaries, and what management action(s) should be implemented in the region to have the greatest impact?	N/A	N/A

Table 2. Study objectives and questions relevant to the RMP ECWG management questions.

Management Question	Study Objective	Example Information Application
1) Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay?	N/A	N/A
2) What are the sources, pathways and loadings leading to the presence of individual CECs or groups of CECs in the Bay?	Indirect through building sampling capacity with the remote samplers.	Implementing monitoring projects to address near-term priority stormwater CECs management questions.
3) What are the physical, chemical, and biological processes that may affect the transport and fate of individual CECs or groups of CECs in the Bay?	N/A	N/A
4) Have the concentrations of individual CECs or groups of CECs increased or decreased in the Bay?	Indirect through building sampling capacity with the remote samplers.	Design and initiate monitoring capable of informing general understanding of changes in CECs presence in the stormwater pathway.
5) Are the concentrations of individual CECs or groups of CECs predicted to increase or decrease in the future?	N/A	N/A
6) What are the effects of management actions?	N/A	N/A

Approach

RMP scientists are currently testing two very different remote stormwater samplers. The first, the compact “SFEI Mayfly" is based on a USEPA in-stream remote sampling device (Kahl et al., 2014) which collects whole water samples using a micropump (USGS is currently developing a similar device), and the EnviroDIY Mayfly (https://www.envirodiy.org), which was designed as a citizen science watershed monitoring device with telemetric data logging capability. SFEI has combined and modified these designs to use sensor measurements (conductivity, temperature, depth) and programmed collection rules (e.g., time intervals, interval and total volumes of collection, minimum and/or maximum salinity and depth ranges) to trigger sample collection. The sampler is outfitted with telemetry such that near-real-time (15 minute interval) measurements are available via the web. In wet season 2022/2023 the SFEI Mayfly was successfully field tested using several deployment approaches, proving its suitability for use in fixed installations (attached to a bridge piling or anchored to an item on a creek bank) and suggesting that other less tightly secured deployment options may also be feasible. These samplers would be less expensive, less labor-intensive, and offer much greater sampling location flexibility compared to traditional commercial remote samplers.

If the SFEI Mayfly sampler is selected, several refinements are planned, including revising the sample collection programming, seeking replacements for parts identified as containing chemicals from the organophosphate ester family, and adding the ability to use telemetry to reprogram the sampler remotely.

The second remote sampler option being tested is a traditional automated pumping sampler (ISCO 6712). These samplers are placed on the side of or above the channel with tubing extending into the channel. This traditional sampling approach is well-proven, although, as with the SFEI Mayfly samplers, blank samples have been collected and results will determine for which chemicals the samplers have acceptable levels of blank contamination. Another case where an ISCO may be preferable is for sites or studies where large numbers of discrete grab samples are desired; some configurations of ISCO samplers can accommodate up to 24 separate bottles. The practical limit of the Mayfly is currently 4 bottles/containers. Deployment of the ISCO samplers is anticipated to be more labor-intensive (securing the conduit and tubing in the channel, housing the ISCO or leaving it outside a lock box, which leaves it vulnerable to vandalism) and overall more expensive (due to the cost of the sampler, tubing and cleaning costs for the tubing, as well as a more intensive effort to deploy) than the SFEI Mayfly samplers.

To evaluate the feasibility of using these remote samplers for the stormwater CECs monitoring program, SFEI conducted side-by-side blank testing of the two samplers (SFEI Mayfly and an ISCO model 6712) to evaluate potential for sample contamination for four CECs families of interest to the RMP (PFAS, OPEs, bisphenols, and vehicle/tire contaminants). In parallel with analyzing these samples, the laboratory (SGS/AXYS) will be conducting container adherence testing of the flexible LDPE containers preferred for use with the SFEI Mayfly with the same four CECs families. We are awaiting the results from the laboratory. However, even if the flexible containers prove to be unsuitable for specific CECs, the SFEI Mayfly may still be able to collect into a different type of container instead of or in addition to the flexible container.

After RMP scientists evaluate the laboratory results, the sampler selection will be made in consultation with the Stormwater CECs Stakeholder-Science Advisor Team (SST). The SST includes representatives from the Steering Committee and Technical Review Committee, as well as science advisors and stakeholders. This decision is anticipated in summer 2023, at which time we will develop the remote sampler purchase scope and budget in consultation with and under the oversight of the SST. We plan to move this process forward quickly once the sampler is selected, as we propose to use the samplers to pilot implementation of the new Stormwater CECs Monitoring Approach in wet season 2023/2024.

In the unlikely event that the QA/QC testing rules out the use of both types of remote samplers for stormwater CEC sampling, the purchase proposal will be scaled down and unused funds will be returned to the RMP.

<u>Task 1: Develop scope and budget for sampler purchase</u>
We will develop a scope and budget for remote sampler purchase under the oversight of the SST. It will subsequently be provided to the SC for final approval.

<u>Task 2: Remote sampler purchase/construction</u>
In addition to purchasing equipment (e.g., parts for SFEI Mayfly construction or ISCO samplers, installation supplies), the sampler purchase task may include labor to construct the samplers (SFEI Mayfly), to refine the design and operation of remote samplers (e.g., improving tidal adjustments, adding the ability to reprogram the samplers without physically revisiting the site providing more flexibility to better tailor the collection to the site and event characteristics), to refine methods for sampler installation, and to obtain permits for any long-term installations.

We roughly estimate that the budget would pay for purchase/construction and installation setups for about a dozen SFEI Mayfly samplers or about half a dozen ISCO samplers. For the SFEI Mayfly, this estimate includes cost for refinement of the sampler design and could include permitting and installation setups at up to three fixed, long-term locations. For the ISCO option, this estimate includes permitting and installation housing at up to three fixed, long-term installation locations. Purchase and installation plans and refined cost estimates will be developed under Task 1.

Budget

The proposed budget includes labor and direct costs. Hours and costs for the sampler purchase are not listed below and will be estimated when the purchase scope is developed.

Expense	Estimated Hours	Estimated Cost
Labor		
Task 1: Develop scope and budget for remote sampler purchase	35	$7,000
Task 2: Remote sampler purchase/construction/methods	TBD	TBD
Direct Costs		
Equipment and supplies		TBD
Remaining tasks (primarily equipment)		$173,000
Grand Total		**$180,000**

Budget Justification

SFEI Labor
Labor hours for SFEI staff to complete all project elements.

Direct Costs
Other direct costs are anticipated to include sampler equipment, and other miscellaneous sampler-related supplies. Estimates of other direct costs will be provided in the purchase budget.

Early Funds Release Request
If this proposal is approved, we request early release of funds for use in 2023 to ensure samplers are available to initiate monitoring during the 2023/2024 wet season.

Reporting

Reporting for Task 1, Scope and budget for sampler purchase, will be the scope and budget presented for SST review and SC approval. Reporting for the sampler purchase will be determined in conjunction with the scope and budget. Reporting may be combined with deliverables for other related projects.

References

Kahl, M.D., Villeneuve, D.L., Stevens, K., Schroeder, A., Makynen, E.A., Lalone, C.A., Jensen, K.M., Hughes, M. Holmen, B.A., Eid, E., Durhan, E.J., Cavallin, J.E., Berninger, J., and Ankley, G.T. 2014. An inexpensive, temporally integrated system for monitoring occurrence and biological effects of aquatic contaminants in the field. Environmental Toxicology and Chemistry, Vol. 33, 7, pp 1584-1595.

Proposal: Watershed Dynamic Model (WDM) Maintenance

Summary: This project will fund the maintenance of the Watershed Dynamic Model (WDM). This proposal provides a list of tasks that can be done with the maintenance fund and proposes a process to decide on which of the maintenance activities and documentation are needed each year. The maintenance tasks will be proposed early each year and submitted to the Steering Committee for approval after consultation with the Modeling Council of Wisdom (COW). A log of model improvements and modifications will be updated by the end of each year. Model simulations of updated time series will be uploaded to SFEI's data portal.

Estimated Cost: $50,000 per year
Oversight Group: SPLWG, Modeling Council of Wisdom (COW)
Proposed by: Tan Zi, Pedro Avellaneda, and Lester McKee
Time Sensitive: Yes

PROPOSED DELIVERABLES AND TIMELINE

Deliverable	Due Date
1. Proposed maintenance tasks	April each year
2. Updated modeling log and new modeling output	December each year

Background

The Watershed Dynamic Model has been developed to support the management questions relevant to sources, pathways, and loadings of sediment and contaminants with continuous support from the RMP (Zi et al., 2021, 2022). The WDM will be used to provide watershed load estimates for sediment, PCBs, Hg, and future contaminants as appropriate, and provide insights into data gaps and monitoring design. Changes associated with control measures, land-use and climate change, or other scenarios can be explored by utilizing WDM and these can be used as boundary conditions for the in-Bay dynamic model to explore water quality and biological responses in the Bay to changing watershed management conditions (Table 1).

Like any other piece of equipment, tool, or model, the WDM requires regular updates, calibration, improvements, and technical support to remain accurate and relevant. For the WDM to be a valuable and immediately available tool for supporting the different RMP Workgroups and every evolving management question, a maintenance fund will ensure that there are adequate resources available to address issues such as data updates, model calibration, and bug fixes. It also allows for ongoing evaluation of the model's performance, which is essential for maintaining its accuracy and reliability. Additionally, a maintenance fund will support capacity building activities, such as training for model users, updating model documentation and data sharing portal. Overall, having a maintenance fund for a watershed model is essential for its continued functionality, usability, and value in supporting RMP workgroups.

Study Objectives and Applicable RMP Management Questions

This proposed fund will provide the sustainability that the existing WDM needs to support the SPLWG high-level management questions as well as the SPL-relevant management questions of other RMP workgroups. The objectives of the project and how the information will be used are shown in Table 1.

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

Management Question	Study Objective	Example Information Application
SPLWG 1) What are the loads or concentrations of pollutants of concern from small tributaries to the Bay?	Provide a modeling platform for watershed load estimation	The model will produce an estimate of PCBs and Hg concentrations and loads at each individual watershed.
SPLWG 2) Which are the “high-leverage” small tributaries that contribute or potentially contribute most to Bay impairment by pollutants of concern	Provide a modeling platform that can be linked with in-Bay model to identify the ‘high-leverage’ tributaries	Estimates produced by WDMI at PMU regions can be provided to in-Bay modeling to explore relative loading rates and the transport and fate of those loads into specific priority margin areas, operational landscape units, or RMP Bay segments.
SPLWG 3) How are loads or concentrations of pollutants of concern from small tributaries changing on a decadal scale?	Provide a modeling platform for trend analysis and management scenario predictions	Support for the 2028 PCB TMDL update. 1. Provide a new robust estimate of watershed PCB loads to the Bay. 2. The load reductions from control measures could be estimated via the control measure module and can be used to assess trends for individual watersheds and the region as a whole.
SPLWG 4) Which sources or watershed source areas provide the greatest opportunities for reductions of pollutants of concern in urban stormwater runoff?	Provide a modeling platform for identifying the watershed with high loading rate	Model outputs of PCBs and Hg will help identify high yield areas that can be targeted for management actions.
SPLWG 5) What are the measured and projected impacts of management action(s) on loads or concentrations of pollutants of concern from the small tributaries, and what management action(s) should be implemented in the	Provide a modeling platform for management action scenarios test and evaluation	Management actions, both existing and planned or anticipated, could be evaluated in the model through scenario runs. This could be used to support the

region to have the greatest impact?		2028 PCB TMDL reevaluation by providing a reasonable assurance prediction of likely future load reductions with further management effort.
PCBWG 1a) What would be the impact of focused management of priority margin unit (PMU) watersheds?	Provide a modeling platform for management action scenarios test and evaluation at PMU	Estimates watershed loadings at PMU regions given different management scenarios, and provides the boundary conditions to in-Bay modeling.
ECWG 2) What are the sources, pathways and loadings leading to the presence of individual CECs or groups of CECs in the Bay?	Provide a modeling platform for watershed CECs load estimation	Estimates stormwater loading for specific CEC.
ECWG 4) Have levels of individual CECs or groups of CECs changed over time in the Bay or pathways? What are potential drivers contributing to change?	Provide a modeling platform for CECs stormwater pathway loading estimation and scenario tests for pathway contributions	Estimates the changes of stormwater loading for specific CEC under different scenarios.
MPWG 3)What are the sources, pathways, processes, and relative loadings leading to levels of microplastics in the Bay?	Provide a modeling platform for stormwater MP load estimation	Estimates watershed loadings of microplastics.
SedWG 3) What are the sources, sinks, pathways, and loadings of sediment and sediment-bound contaminants to and within the Bay and subembayments?	Provide a modeling platform for watershed sediment load estimation	Predict watershed sediment loadings under different future scenarios.

Approach

The model maintenance fund will be used for the following types of activities.

1. Model simulation extension: Model output with the latest water year is desirable to support answering RMP management questions and providing boundary conditions to in-Bay modeling. A maintenance fund will support annual model output extension by processing the weather data and applying the WDM for the latest water year. This could be done every year.
2. Model performance evaluation: Regular evaluation of the WDM's performance is essential to identify any deviations or inaccuracies and to assess its effectiveness in meeting its intended goals. The maintenance fund will support ongoing data analysis, performance evaluation, and reporting on the model's

performance to stakeholders. This might need to be done periodically every three years.

3. Data updates and calibration: WDM relies on accurate and up-to-date data, including precipitation, streamflow, land use, and soil data. A maintenance fund can support regular updates of these data, as well as recalibration of the model to improve its accuracy and reliability. We propose to do recalibration every five years.
4. RMP WDM meeting: As WDM starts to support multiple workgroups within RMP, it needs a platform so the maintenance fund can be used to support to host a WDM-specific meetings to introduce the progress of WDM relevant projects, discuss modeling needs with stakeholders, and engage local modelers and modeling experts to help improve the WDM. We propose to have an annual RMP WDM-specific meeting.
5. Capacity building and training: Ensuring that users of the WDM are trained and equipped with the necessary skills to operate the model effectively is crucial. The maintenance fund will support capacity building activities, such as model training workshops, providing educational materials to continuously improve the model's usability and effectiveness. This might be triggered when a new staff person is hired or when a stakeholder requests training.
6. Model updates and improvements: WDM may need periodic updates and improvements to incorporate new scientific findings, refine the tools for data process and analysis, or enhance model functionality. The maintenance fund will support minor development efforts to update and improve the model, such as adding new features, or expanding its capabilities. Triggered as necessary.
7. Outreach and communication: The maintenance fund will support outreach and communication efforts, such as developing educational materials, developing and updating the web portal for data and results sharing, and disseminating information through various channels to promote the understanding and use of the model. The fund can be used to support organizing modeling workshops for stakeholders and with modeling groups from other regions (e.g. Chesapeake Bay). It can also support SFEI staff to participate in relevant conferences to communicate and outreach WDM modeling efforts. Triggered as necessary.
8. Technical support and troubleshooting: Users of the WDM may encounter technical issues or require assistance in troubleshooting problems. The maintenance fund will provide resources for technical support, such as engaging external experts to provide assistance when needed.

Among these tasks, we envision the first four tasks are regularly scheduled activities. Part of the funds can be reserved each year for a larger task such as the recalibration (proposed to recalibrate the model every 5 years or if there are major data updates, such as land use or advances in the methods for inputting climate data). Other tasks are based on the needs, and the modeling team will provide a proposed task list and estimated budget for COW review, TRC review, and SC approval. The end-of-year cost (unused maintenance fund is rolling over to the next year) and the tasks that have been completed will be documented in the model development log, and presented to the SPLWG and COW.

Tasks and Budget

The tasks of model maintenance can vary from year to year. We proposed a standardized procedure to conduct WDM maintenance activities each year:

Step 1. At the beginning of each calendar year, review a one year plan of model maintenance activities and provide justification for priorities for model maintenance for COW review and address any concerns.
Step 2. Submit revised model maintenance work plan for TRC review and SC approval.
Step 3. Host a RMP WDM modeling specific meetings at mid-year to update the work. progress and planning, and gather feedback from stakeholders and scientific advisers.
Step 4. Complete model maintenance activities.
Step 5. Update the model development log and report outcomes to RMP WGs and the COW.

The proposed budget includes estimated hours for the tasks. Estimations of hours and costs for maintenance tasks proposed for each following year are not included. If the fund is not used up by proposed tasks in one year, the fund can be rolled over to the next year.

Expense	Estimated Hours	Estimated Cost
Labor		
Task 1: Extend the modeling results to the latest water year	80	$12,000
Task 2: Re-evaluate modeling results every 3 years	160	$24,000 (8,000 per year)
Task 3: Recalibrate model every 5 years	320	$48,000 (9,600 per year)
Task 4: RMP WDM meeting and preparation	40	$6,000
Modeling development log update	40	$6,000
Other proposed activities	TBD	$8,400
Annual Budget		**$50,000**

<u>Budget Justification</u>

SFEI Labor:
Labor hours for SFEI staff to complete all project elements.

Reporting

A proposed model maintenance task list and budget will be sent to the COW for review and for SC approval. The proposed update will be presented at SPLWG. The model development log will be updated each year and an annual summary of activities completed will be provided to the SPLWG and COW.

References

Zi, T.; Mckee, L.; Yee, D.; Foley, M. 2021. San Francisco Bay Regional Watershed Modeling Progress Report, Phase 1. SFEI Contribution No. 1038. San Francisco Estuary Institute: Richmond, CA.

Zi, T, A. Braud, L. McKee, and M. Foley. 2022. San Francisco Bay Watershed Dynamic Model (WDM) Progress Report, Phase 2. Report prepared for the Sources Pathways and Loadings Workgroup of the Regional Monitoring Program for Water Quality. SFEI Contribution #1091. San Francisco Estuary Institute, Richmond, California.

PCBWG Proposal: Priority Margin Unit Shiner Surfperch PCB Trend Monitoring

Oversight group: PCB Workgroup
Proposed by: Jay Davis, SFEI

Summary

Conceptual site models for PCBs developed for several priority margin units in the Bay identified shiner surfperch as a crucial indicator of impairment in these areas, due to their explicit inclusion as an indicator species in the TMDL, their importance as a sport fish species, their tendency to accumulate high concentrations, their site fidelity, and other factors. The conceptual site models recommend periodic monitoring of shiner surfperch to track trends in the PMUs, and as the ultimate indicator of progress in reduction of impairment. A coordinated sampling of PCBs in shiner surfperch in four PMUs was conducted as an add-on to the 2019 Status and Trends sport fish sampling. Sampling for shiner was attempted but unsuccessful in two PMU areas: Emeryville Crescent and Steinberger Slough. Shiner were successfully collected and analyzed from San Leandro Bay and Richmond Harbor. The mean concentration in San Leandro Bay in 2019 was the highest observed at any of the S&T or PMU stations. Sampling at three stations in Richmond Harbor documented significant spatial variation with in this PMU, and high concentrations at two locations farther away from the open Bay. Repeat sampling of the San Leandro Bay and Richmond Harbor stations is needed to track long-term trends in support of management. Coordination with S&T sampling will yield significant savings in data management and reporting. In addition, a dataset for shiner surfperch will be obtained that is directly comparable across the PMUs and the five locations that are sampled in S&T.

Proposed Funding

1) $20,000

Proposed Deliverables and Timeline

Deliverable	Due Date
Draft section in report on RMP S&T Sport Fish Sampling	Dec 2025
Final section in report on RMP S&T Sport Fish Sampling	Feb 2026

Introduction and Background

Given the large expenditures of funding and effort that will be needed to implement management actions to reduce PCB loads from urban stormwater, a thorough and thoughtful planning effort for science support is warranted. Therefore, the RMP has a PCB Strategy that outlines a multi-year effort to implement the recommendations of the PCB Synthesis Report (Davis et al. 2014) pertaining to:

1. identifying margin units that are high priorities for management and monitoring (priority margin units, or "PMUs"),
2. development of conceptual models and mass budgets for margin units downstream of watersheds where management actions will occur, and
3. monitoring in these units as a performance measure.

The first step (Gilbreath et al. 2015) consisted of a preliminary assessment of margin units downstream of six pilot watersheds that have been prioritized for management actions. The second phase of the PMU workplan consisted of developing conceptual site models for four PMUs: Emeryville Crescent, San Leandro Bay, Steinberger Slough/Redwood Creek, and Richmond Harbor. Conceptual model reports have been completed for Emeryville Crescent, San Leandro Bay, and Steinberger Slough/Redwood Creek (Davis et al. 2017, Yee et al. 2019, 2021). A conceptual model for Richmond Harbor has not yet been developed.

The conceptual model reports included recommendations for efficient long-term monitoring of trends in the PMUs and their response to reductions in loads from the watersheds. The conceptual site models identified shiner surfperch as a crucial indicator of impairment in these areas, due to their explicit inclusion as an indicator species in the TMDL, their importance as a sport fish species, their tendency to accumulate high concentrations, their site fidelity, and other factors. The conceptual site models recommended periodic monitoring of shiner surfperch to track trends in the PMUs, and as the ultimate indicator of progress in reduction of impairment.

A coordinated sampling of PCBs in shiner surfperch in four PMUs was conducted as an add-on to the 2019 Status and Trends sport fish sampling. Sampling for shiner was attempted but unsuccessful in two PMU areas: Emeryville Crescent and Steinberger Slough. Shiner were successfully collected and analyzed from San Leandro Bay and Richmond Harbor. The mean concentration in San Leandro Bay in 2019 was the highest observed at any of the S&T or PMU stations (Figure 1). Sampling at three stations in Richmond Harbor documented significant spatial variation with in this PMU, and high concentrations at two locations farther away from the open Bay (Figure 2).

This proposal outlines a project that would provide sampling of PCBs in shiner surfperch in two of the PMUs, at two of the stations sampled in 2019. This can be done in a cost-effective manner in 2024 by piggybacking on to the 2024 S&T sport fish sampling (Figure 3). This coordination will yield significant savings in data management and reporting, because these results can be easily added to the S&T activities with negligible additional cost. In addition, a dataset for the same species (shiner surfperch) will be obtained that is directly comparable across the PMUs and the five locations that are sampled in S&T. The vision is to continue this approach in future rounds of S&T sport fish sampling, providing data on PCBs in the San Leandro Bay and Richmond Harbor PMUs on a five-year cycle. This sampling design would provide a key element needed to track long-term trends in recovery of the PMUs.

Study Objective and Applicable RMP Management Questions

The objective of this study is to establish baselines for long-term monitoring of PCB concentrations in shiner surfperch in two PMUs.

PCB Strategy Questions Addressed

1. What are the rates of recovery of the Bay, its segments, and in-Bay contaminated sites from PCB contamination?
    a. What would be the impact of focused management of PMU watersheds?

RMP Management Questions Addressed

4. Have the concentrations, masses, and associated impacts of contaminants in the Estuary increased or decreased?
    B. What are the effects of management actions on the potential for adverse impacts on humans and aquatic life due to Bay contamination?

Study Approach

The proposed sampling would be added to the RMP S&T sport fish sampling in 2024. Sampling shiner surfperch at five locations is a critical component of the S&T sampling, with collections made at the San Pablo Bay, Berkeley, San Francisco Waterfront, Oakland, and South Bay locations shown on Figure 3. The proposed sampling would add two more sites as indicated in Figure 4. These PMU sites could be included in the Sampling and Analysis Plan, data management, and the technical report on the S&T sampling, with the negligible additional cost covered by the S&T budget.

In Richmond Harbor, one of the three stations previously sampled will be sampled in this round to minimize costs. The "Back Channel" station will be retained. The Lauritzen Channel station also had high concentrations, but is harder to sample due to debris and the Lauritzen Channel has a no consumption advisory in place due to DDT contamination. The Main Channel station had significantly lower concentrations than the other two stations.

Three composites (20 fish per composite – the standard approach used in S&T) will be collected and analyzed from each PMU site by Moss Landing Marine Lab (MLML). MLML would also measure weight and length of the fish. PCBs would be analyzed as 209 congeners by SGS AXYS. Moisture and lipid will also be determined.

Tasks and Budget

Task 1: Study planning, include PMU shiner in S&T Sampling and Analysis Plan
Task 2: Collect and process samples, include PMU shiner in S&T cruise report
Task 3: PCB analysis

Task 4: Data management and QA, include PMU shiner surfperch in S&T dataset and QA report
Task 5: Include PMU shiner surfperch in S&T technical report

Budget: $20K

Budget breakdown

# of Sites	2
# of Fish Composites per Site	3
# of Samples to Collect	6
Collection Cost per Sample	$ 2,000
Sample collection cost	$ 12,000
Dissection and Comp per Sample	$ 110
Total Dissection and Comp	$ 660
Analytical Cost per Sample	$ 930
# of Field Samples to Analyze	6
QA Samples	1
Total Analytical Cost	$ 6,510
Data Management	$ -
Total Cost	**$ 19,170**

Timing and Deliverables

All deliverables will be incorporated in S&T sport fish deliverables:

- S&T sampling and analysis plan – March 2024
- S&T cruise report – December 2024
- Draft S&T technical report – December 2025
- Final S&T technical report – February 2026

References

Davis, J.A., D. Yee, A.N. Gilbreath, and L.J. McKee. 2017. Conceptual Model to Support PCB Management and Monitoring in the Emeryville Crescent Priority Margin Unit. San Francisco Estuary Institute, Richmond, CA. Contribution #824.

Yee, D., A.N. Gilbreath, L.J. McKee, and J.A. Davis. 2019. Conceptual Model to Support PCB Management and Monitoring in the San Leandro Bay Priority Margin Unit – Final Report. SFEI Contribution No. 928. San Francisco Estuary Institute Richmond, CA.

Yee, D., A.N. Gilbreath, L.J. McKee, and J.A. Davis. 2021. Conceptual Model to Support PCB Management and Monitoring in the Steinberger Slough/Redwood Creek Priority Margin Unit – Final Report. SFEI Contribution #1009. San Francisco Estuary Institute, Richmond, CA.

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Figure 1. PCB concentrations (ppb ww) in shiner surfperch in San Francisco Bay, 2019. Bars indicate average concentrations. Points represent composite samples with 20 fish in each composite. Locations labeled with the same letter did not have significantly different means (Tukey HSD, alpha = 0.05). The colored lines indicating ATL thresholds show the lower end of the ATL ranges. Richmond Harbor and San Leandro Bay were sampled as part of the shiner surfperch special study in 2019.

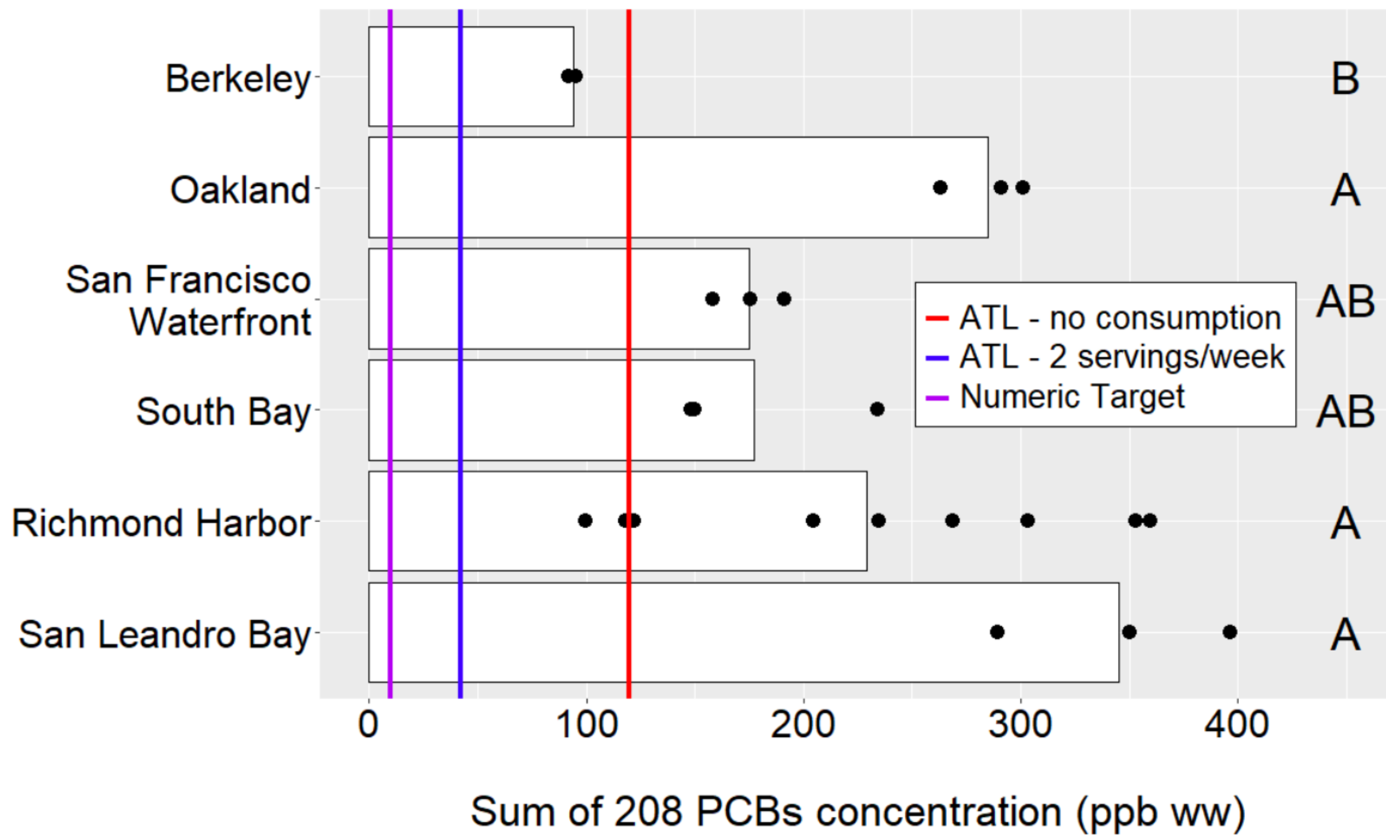

Figure 2. PCB concentrations (ppb ww) in shiner surfperch in Richmond Harbor, 2019. Bars indicate average concentrations. Points represent composite samples with 20 fish in each composite. Locations labeled with the same letter did not have significantly different means (Tukey HSD, alpha = 0.05). The colored lines indicating ATL thresholds show the lower end of the ATL ranges.

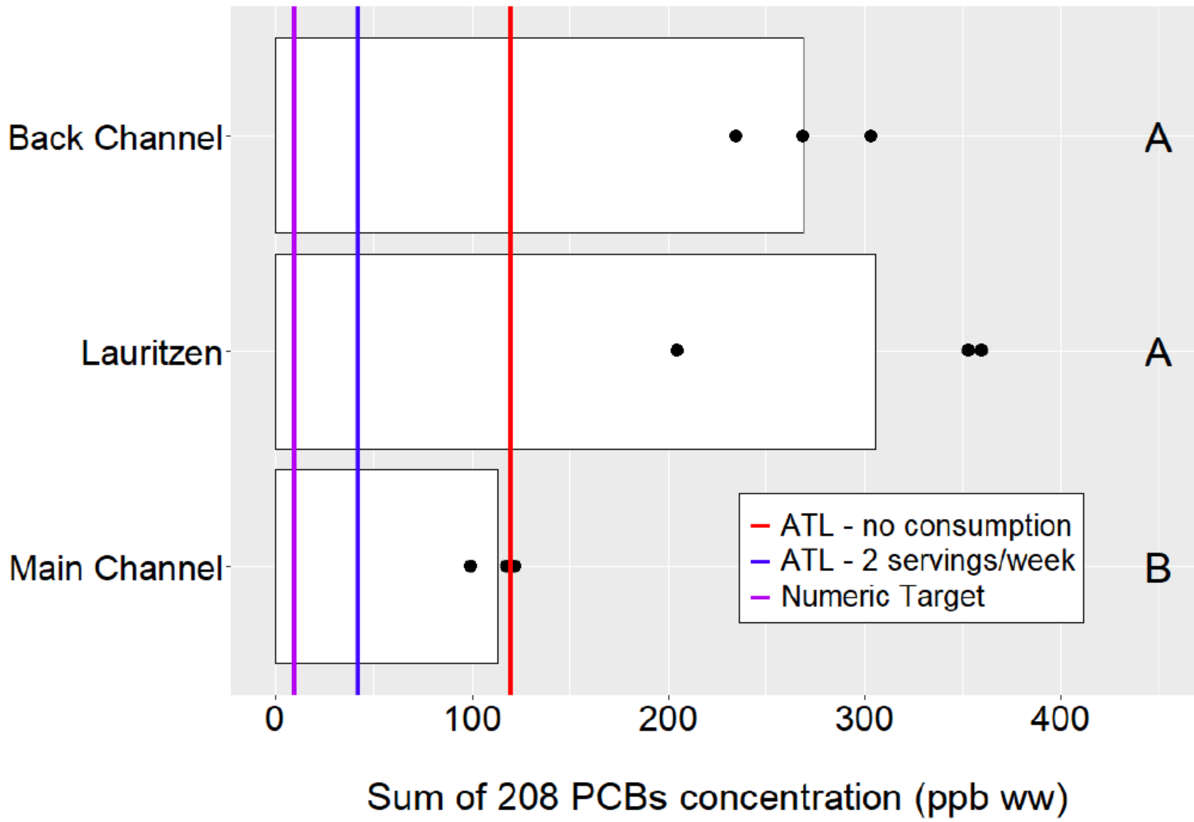

Figure 3. RMP S&T and PMU sport fish sampling locations, 2019.

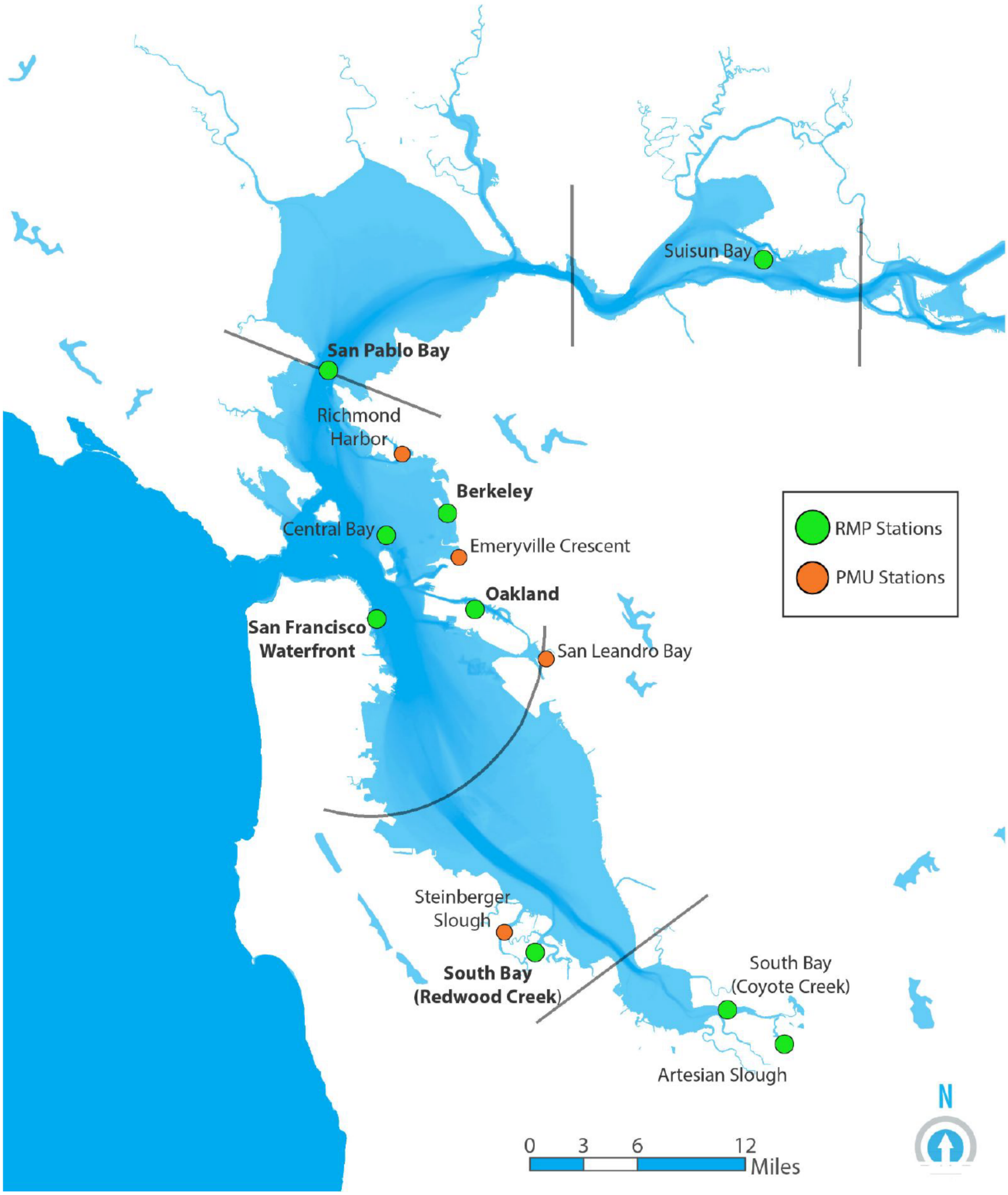

Figure 4. Proposed shiner surfperch sampling locations in the PMUs.

PCBWG Proposal: Monitoring of Sediment Deposition in San Leandro Bay Intertidal Areas

Summary

This study proposes to measure sediment deposition within the San Leandro Bay (SLB) priority margin unit (PMU) using an array of tools, including sediment marker horizons, sediment pins, surface elevation tables, and sediment traps. Areas across a span of distances nearer and further from discharge areas in SLB for watersheds of interest for PCB loading (East Creek, Damon Slough) will be monitored for sedimentation and net sedimentation (i.e., either net deposition or erosion) quarterly over the course of one year to capture seasonal-scale processes. Measurement of grain size in sediment trap material and in surface sediment adjacent to the monitored points for two of the quarterly visits (one in wet season, one in dry season), which may help the parameterization of particle sizes for both the Watershed Dynamic Model (WDM) and in-Bay fate model locally. A potential add-on would be measurement of PCBs in sediment trap material, which will be useful in distinguishing the PCBs in newly settling mobile sediment in comparison to previous sampling efforts characterizing consolidated bed surface sediment.

Estimated Cost:	$76k (basic plan, added options +$20k)
Oversight Group:	PCBWG
Proposed by:	Don Yee
Time Sensitive:	Yes, for summer 2024 SLB model completion (most useful if available before model fully calibrated). Late fall 2023 deployment needed to capture at least one wet season for model validation.

Background

Priority margin units (PMUs) are areas in the Bay near known upland sources of legacy contaminants that are likely to be most impacted by management-driven increases or decreases in pollutant loading. Cores in some vegetated wetlands have shown evidence of reductions in some legacy contaminants. Downward mixing in vegetated wetland areas is reduced due to the vegetation limiting resuspension and bioturbation. However, in many intertidal mudflats, it is unknown if contaminants present in sediment accessible to biota are due to sediment accretion, downward mixing, or some combination of both.

Models of long-term sediment and contaminant fate in PMUs, and the Bay in general, are in development and will require empirical data for the variables being simulated, including net sediment accretion or erosion. Accurate predictions of net sedimentation are critical to estimates of recovery time for persistent legacy pollutants such as PCBs, since a major PCB loss pathway via sediment burial is anticipated to be highly sensitive to net sedimentation rate in both the regional-scale PCB fate model (Davis 2004) and local-scale conceptual models for PMUs such as SLB (Yee et al., 2019).

This study would monitor net sedimentation at sites within San Leandro Bay (SLB) in order to locally calibrate or validate estimates of expected sedimentation obtained by the integration of watershed models of flow and sediment supply (the Watershed Dynamic Model, WDM, Zi et al., 2022) being currently developed at SFEI, and high-resolution hydrodynamic and sediment transport models being developed for SLB, extended from Bay-wide hydrodynamic modeling efforts in DelftFM for the Nutrient Management Strategy (King et al., 2019).

Both WDM and DelftFM have been primarily focused to date on Bay-scale processes and have been initially calibrated to capture average responses at a regional scale, rather than within localized areas like SLB. As a result, data to locally calibrate and validate processes for SLB specifically will be needed to make predictions of recovery rates sufficiently accurate to project recovery rates from legacy contamination, and responses to reductions in inputs of sediment-bound pollutants.

Study Objectives and Applicable RMP Management Questions

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

Management Question	Study Objective	Example Information Application
1. What are the rates of recovery of the Bay, its segments, and in-Bay contaminated sites from PCB contamination? a. What would be the impact of focused management of PMU watersheds?	Empirical sediment downward and net flux Grainsize of settling and bed sediment (Optionally PCBs in new settling sediment).	1a. Sediment burial rate input to simple PCB box model, or downward flux and net sedimentation target for dynamic sediment loading and fate models Grainsize validation for WDM loads and SLB transport models (Seasonal settling PCBs compared to event stormwater PCBs)
b. What would be the impact of management of in-Bay contaminated sites?		1b. Not directly addressed. But repeated sediment trap PCBs in future might indicate progress.

Approach

This study proposes to measure sediment deposition rates within the San Leandro Bay PMU using an array of tools, including sediment marker horizons, sediment pins, surface elevation tables, and sediment traps. Net sediment accretion or erosion estimated using these methods will be useful for calibrating and validating models of long-term sediment fate.

Sediment marker horizon methods planned will include plastic lighting grids and sediment plates (http://www.tidalmarshmonitoring.net/monitoring-methods-marker-horizons.php). The plastic grid marker will be resistant to erosion and may be able to show net erosion (up to the thickness of the grid). However, larger degrees of erosion would not be shown as the grid would simply drop down to the eroded surface. Similarly, sediment plates can show net accretion on top of the plate, or net erosion, if the plate is supported by a deeper rod less susceptible to settling to the scoured surface.

Sediment pins placed on the corners of the marker horizon plots will be used as visual markers to find the plots and provide evidence of net accretion or erosion. Sediment pins are somewhat subject to localized erosion around their points of insertion (larger for larger diameter pins), so paired sediment pins driven to equal heights spaced several feet apart, with a contractor's level carried to the field spanning them, can be used as a portable surface elevation table (SET), by measuring the distance to the sediment surface at several points from the spanning level (Prof. John Rybczyk, pers. comm.).

About 1-2m away, but at approximately the same elevation as the marker/pin/SET assemblies, mason jars equipped with coarse mesh (¼") stainless steel screened lids will be placed as sediment traps to capture downward sediment flux, which combined with the net sedimentation rate can be used to back-calculate resuspension flux. The screening will reduce disturbance of the trap contents by biota or waves and currents.

The proposed scope is for eight areas (Figure 1), with two tidal elevations each (16 installations total). Measurements in East Creek and Damon Slough are proposed at areas near (~20 m) and further (~100 m) from the main channels. An additional site pair midway between these two areas will provide information on processes further from those inputs. Site pairs further away from these inputs on the east and west sides of Arrowhead Marsh, areas without immediately proximate tributary input, and near the channel on the south end of Alameda, near SLB's exchange point with Central Bay, can provide information on longer distance transport processes, and interactions near the Bay boundary.

The deployments will be visited quarterly to check on their status and measure estimates of sediment accretion or erosion. Deployment is estimated to require several days of field work for a crew of two people. An initial site visit about a month after deployment is planned to inspect the integrity of the installations and make adjustments as needed (e.g., copper screening may be used instead on sediment traps if excessive biofouling occurs).

If the deployments remain intact, subsequent quarterly visits are planned to make measurements and collect sediment traps. The effort is scalable, and could include more areas (e.g., sites near the entry of Elmhurst Slough and San Leandro Creek, and Alameda Channel), or more elevations in each area.

Figure 1. Proposed locations for sediment markers and traps

Grain size characterization of sediment trap material and in surface sediment near the deployments for one event each in wet and dry season (16 traps in 2 events + bed sediment, + QC = ~50 samples) is planned. An optional add-on monitoring in 2 other events (when field measurements are being taken anyway) would provide additional information on temporal variability for more (likely seasonal transition or primarily dry) periods.

A second add-on would be measurement of PCBs in sediment trap material, with the approximate cost of $14k (8 deeper MLW points + QC = ~10 samples). Costs for the basic monitoring plan and these options are shown in Table 1. The study duration, frequency of visits, and number of sites can also be scaled somewhat.

Locations are placed at elevations around MSL and MLW near boundary inputs of sediment and water, and in central areas around Arrowhead Marsh to capture the interaction of inputs with local transport processes.

Table 1. Estimated Cost:

Expense	Estimated hours	$ Cost
Labor		
Planning & mgmt	60	10500
Field Work, pre & post	230	37000
Reporting	80	14000
Direct Costs		
Equipment		2000
Travel		400
Subtotal		**63900**
Subcontracts		
Grainsize (2 events+ 1x bed sed +QC)		7900
Data mgmt/reporting	26	3900
Shipping		300
Subtotal grainsize		**12100**
Total (basic plan)		**76000**
Optional		
Grainsize (other 2 events)	(lab + data mgmt/reporting costs)	**(+5900)**
PCBs (Feb 2024 MLW traps+QC)		9200
Data mgmt/reporting	30	4500
Shipping		600
Subtotal PCBs		**(+14300)**

Deliverables and Schedule

Monitoring plan development	Oct 2023
Marker deployment	Mid-late Nov 2023
Site Revisits & Measurements	Dec 2023, Feb, May, Aug, Nov 2024
Lab analysis grainsize	Feb, May, Aug, Nov 2024 (+2mo lab turnaround)

Lab analysis PCBs	Feb 2024 (+2mo)
Draft technical report	Feb 2025
Final report and data upload	April 2025

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