

REGIONAL MONITORING PROGRAM • UPDATE 2023



2023 RMP UPDATE

A Report of the Regional Monitoring Program for Water Quality in San Francisco Bay



NOTE TO READERS: The RMP produces two types of summary reports: *The Pulse of the Bay* and the *RMP Update*. *The Pulse* focuses on Bay water quality and summarizes information from all sources. The *RMP Update* has a narrower and specific focus on highlights of RMP activities. The next *Pulse of the Bay* will be published in 2024.

DIGITAL VERSIONS of all RMP Updates are available at: www.sfei.org/rmp/update

DIGITAL VERSIONS of all Pulses are available at: www.sfei.org/rmp/pulse

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PREFACE

The overarching goal of the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) is to answer the highest priority scientific questions faced by managers of Bay water quality.

The RMP is an innovative collaboration between the San Francisco Bay Regional Water Quality Control Board, the regulated discharger community, the San Francisco Estuary Institute, and many other scientists and interested parties.

The purpose of this document is to provide a concise overview of recent RMP activities and findings, and a look ahead to significant products anticipated in the next two years.

The report includes:

- a brief summary of some of the most noteworthy findings of this multifaceted Program;
- a description of the management context that guides the Program; and
- a summary of progress to date and future plans for addressing priority water quality topics.

Photo (previous page): Deploying a conductivity, temperature, and depth (CTD) instrument package on the 2023 Status and Trends sediment cruise.

View from the R/V Questuary on the 2023
Status and Trends sediment cruise. ►

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R/V QUESTUARY

FURUNO

Program **HIGHLIGHTS**



The R/V Questuary, the vessel used for the 2023 Status and Trends sediment cruise.

The RMP Top Ten: Recent Activities and Accomplishments

1

General:

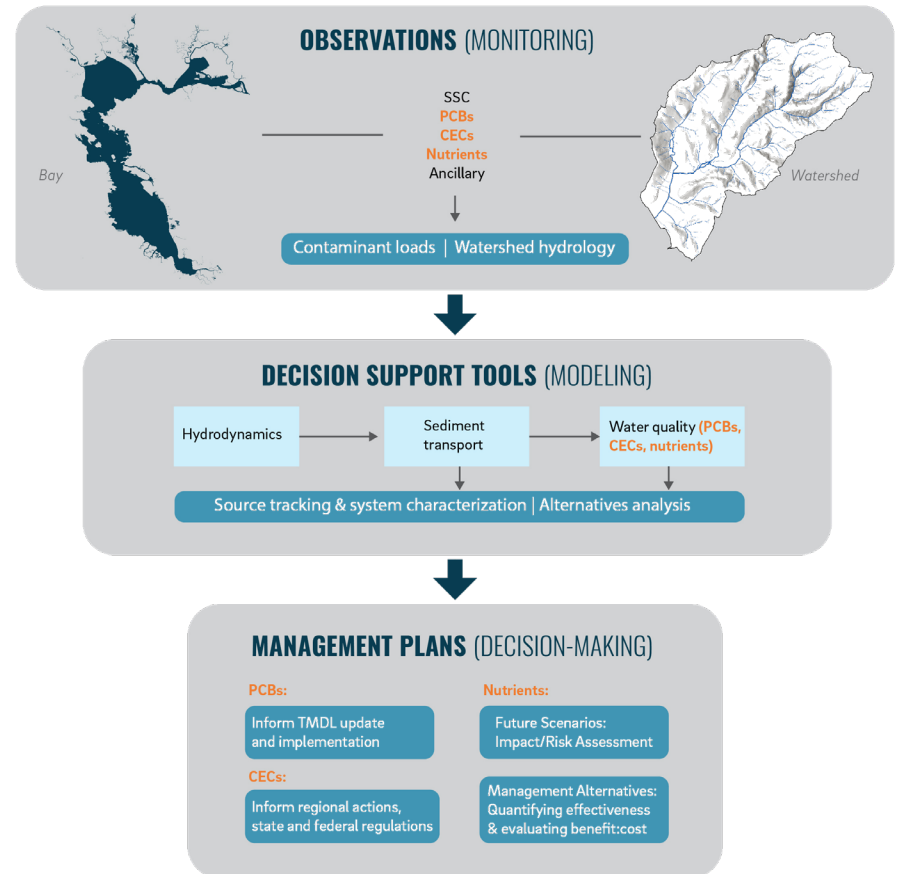
Destination Clean Bay Proposal Funded by USEPA

The US Environmental Protection Agency (USEPA) manages a competitive grant program, known as the San Francisco Bay Water Quality Improvement Fund, to support projects to protect and restore San Francisco Bay. From 2008, when the program began, to 2022 it awarded over \$71.4 million in 59 grant awards. In 2023 available funding increased and USEPA was able to fund 24 new projects totaling over \$50 million.

Destination Clean Bay: Decision Support Tools for Multi-Benefit Water Quality Improvements, a joint proposal of the RMP and the Nutrient Management Strategy (NMS), was one of the projects funded in 2023. USEPA will provide \$3 million for the four-year project. Destination Clean Bay builds on the strong foundation established by the RMP and the NMS to identify the optimal path toward the multi-benefit management of pressing water quality issues. SFEI will work with RMP and NMS stakeholders to monitor contaminants to support the development of models and decision support tools that provide managers with the information needed to

evaluate nutrient management scenarios for a healthy Bay, identify PCB and emerging contaminant reduction opportunities to support aquatic life and human health, and prioritize sediment management needs for restoration and community resilience. The development of open-source, publicly available models will support analysis of future conditions for PCBs, CECs, sediment, and nutrients based on scenarios of management actions and climate-driven changes in the Bay Area.

Project partners include the RMP, NMS, Regional Water Quality Control Board, and Bay Area Clean Water Agencies (BACWA).



MORE INFORMATION

SFEI Website: <https://www.sfei.org/news/sfei-awarded-over-7-million-bay-restoration-and-community-partnerships>

Destination Clean Bay will follow a tiered approach to informing consequential, near-term management decisions to improve the health of San Francisco Bay.



General: RMP Multi-Year Plan Update

The goal of the RMP is to collect data and communicate information about water quality in San Francisco Bay in support of management decisions. This goal is achieved through a cooperative effort from a wide range of regulators, dischargers, scientists, and environmental advocates. This collaboration has fostered the development of a multifaceted, sophisticated, and efficient program that has demonstrated the capacity for considerable adaptation in response to changing management priorities and advances in scientific understanding. In order to fulfill the RMP goal, the Program also has to be forward-thinking and anticipate what decisions are on the horizon, so that when their time comes, the scientific knowledge needed to inform the decisions is at hand.

The RMP Multi-Year Plan (MYP) documents the Program's continual adaptation. The MYP is an annually updated summary of the decisions and management questions that guide the RMP and the studies that are being performed to address them. The MYP summarizes the planned activities for the various elements of the RMP (including Status and Trends monitoring and the studies performed under the five workgroups) for the next several years. An updated version of this living document is published every year in January. The management questions are

revised once every five to ten years through a thoughtful and deliberate stakeholder process. Workgroup study plans, on the other hand, are more dynamic and are updated annually.

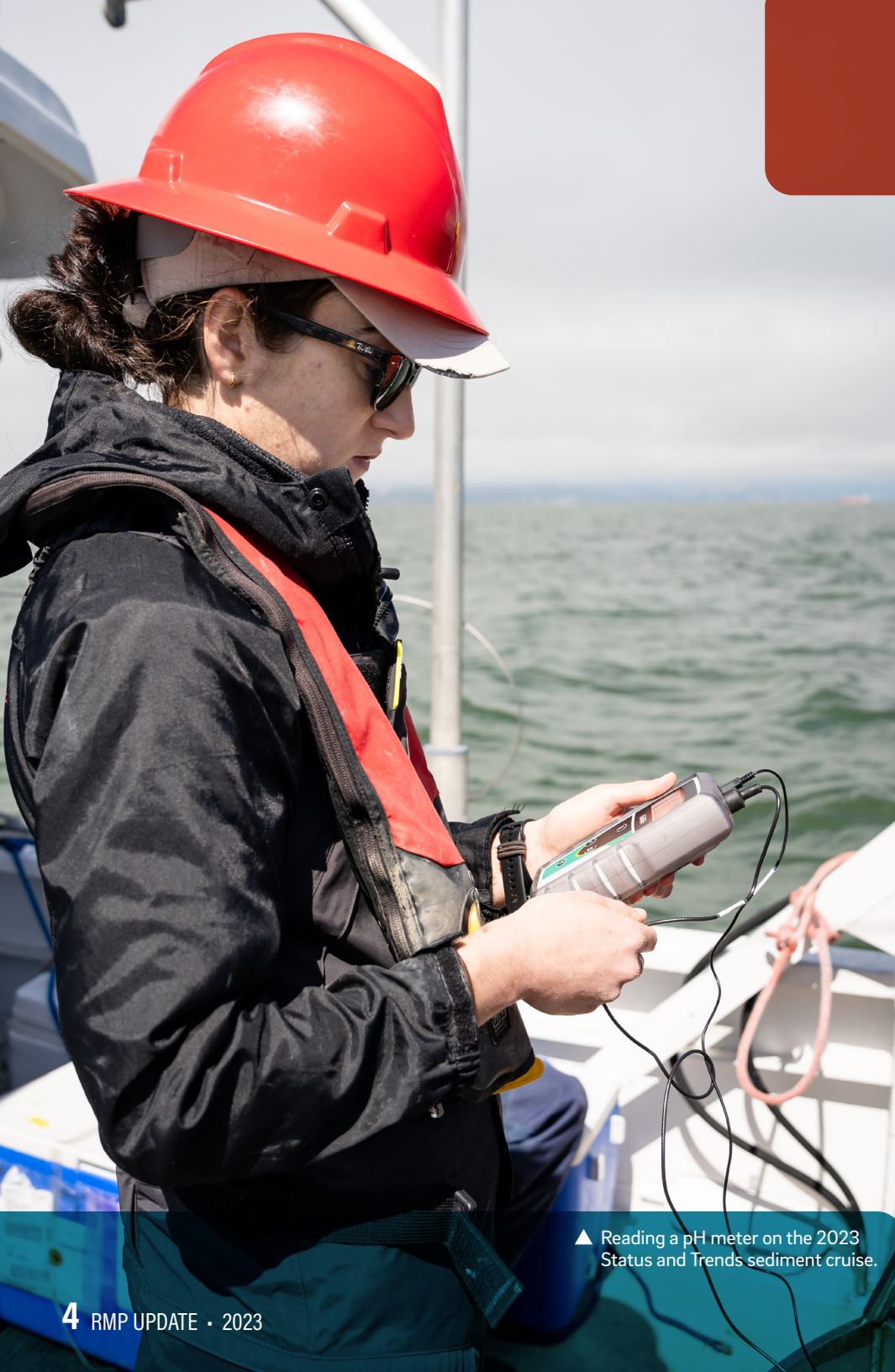
A major update of the MYP is in progress for January 2024. For this edition, each RMP workgroup (Emerging Contaminants; Sources, Pathways, and Loadings; Sediment; Microplastics; and PCB) will have updated their lists of guiding decisions and management questions and the associated study plans for the next several years.

MORE INFORMATION

RMP web page (the updated Multi-Year Plan will be posted here under Governance/General/Key Resources): <https://www.sfei.org/programs/rmp>



▲ Nic Shields, skipper of the R/V Questuary, the vessel used for the 2023 Status and Trends sediment cruise.



In 2020 a collaborative, RMP-supported study of contaminants of emerging concern in urban stormwater (page 14) found a highly toxic tire-related contaminant - 6PPD-quinone (6PPDQ) - at four Bay Area sites at levels that would be lethal to coho salmon. 6PPDQ is a transformation product of the antioxidant chemical 6PPD, which is added to tires to reduce cracking and extend their useful life. Both 6PPD and 6PPDQ wash into streams along with tire wear particles when it rains. 6PPDQ was recently discovered to be responsible for high levels of coho salmon mortality in Puget Sound streams. Coho salmon no longer reside in San Francisco Bay and its streams, but they are being restored to coastal streams from Santa Cruz to Sonoma County. Mounting evidence indicates that 6PPD-quinone also poses threats to other aquatic organisms.

In July 2023, the California Department of Toxic Substances Control (DTSC) adopted a rule that requires manufacturers of tires for sale in California to evaluate safer alternatives to 6PPD. DTSC's regulation to add motor vehicle tires containing 6PPD to the state's list of Priority Products took effect on October 1, 2023. Domestic and foreign manufacturers will have until November 30, 2023, to notify DTSC if they manufacture 6PPD-

containing tires that are placed into the stream of commerce in California. 6PPD will be subject to an alternatives analysis process that requires manufacturers to identify and compare the impacts of potential alternatives with those of 6PPD across its life cycle, with the goal of ensuring the continued safety of the tires on California's roads while protecting California's fish populations and the communities that rely on them.

MORE INFORMATION

SFEI website: <https://www.sfei.org/news/sediment-survival-report-released>

SFEI fact sheet on Microplastics from Tire Particles in San Francisco Bay: <https://www.sfei.org/documents/microplastics-tire-particles-san-francisco-bay-factsheet-0>

DTSC news release: https://dtsc.ca.gov/2023/07/26/news-release_t-06-23/

▲ Reading a pH meter on the 2023 Status and Trends sediment cruise.



CECs: PFAS in Bay Water and Wastewater

In a recent study, RMP scientists detected PFAS, also known as “forever chemicals,” at parts per trillion concentrations in the waters of the Bay. The specific chemicals found included the well-studied PFOS and PFOA, as well as their replacements. These compounds are persistent and toxic. Levels in Bay water do not appear to pose risks to wildlife but are consistent with concern for people who eat fish from the Bay regularly.

Bay Area wastewater agencies are partnering with the RMP on a study of the sources of PFAS to wastewater treatment plants. The regional study examined influent, effluent, and biosolids. Higher concentrations observed in samples from some residential neighborhoods and specific industries indicated the importance of source control to reduce PFAS in the environment. Preliminary results using an advanced method that identifies the presence of unknown PFAS precursors pointed to the importance of dealing with PFAS as a broad class.

The state of California has passed bans on PFAS in some specific products to reduce

harmful exposures. For example, California will become the first state in the U.S. to ban the use of PFAS chemicals on apparel and textile products, starting January 2025. Other recent actions cover PFAS in cosmetics, children's products, carpets and rugs, paper-based food packaging, and fire-fighting foams.

PFAS have also been detected in Bay sport fish, bird eggs, and harbor seals, and in wastewater and stormwater (page 14) discharges. Sustained, multi-matrix monitoring of this important class of contaminants of emerging concern is a high priority for the RMP.

MORE INFORMATION

SFEI Technical Reports:

Mendez, M., Lin, D., Wong, A., Yee, D., and Sutton, R. 2021. Study of Per- and Polyfluoroalkyl Substances in Bay Area POTWs Phase 1 Memo. SFEI Contribution No. 1145. San Francisco Estuary Institute, Richmond, CA.

Mendez, M., Trinh, M., Miller, E., Lin, D., and Sutton, R. 2022. PFAS in San Francisco Bay Water. SFEI Contribution No. 1094. San Francisco Estuary Institute, Richmond, CA.



CECs: Ethoxylated Surfactants in Wastewater, Stormwater, and Bay Water

Ethoxylated surfactants are widely used ingredients in a variety of consumer and industrial products. For decades, related water contamination was assumed to be primarily due to ethoxylated surfactants in laundry detergents, which would be degraded via wastewater treatment to a few more persistent degradates. As a result, monitoring has focused on a subset of smaller (short-chain) contaminants in wastewater effluent and receiving waters, and management actions have focused on laundry detergent and other cleaning products.

A RMP study that was just published in the journal ACS EST Water provided evidence that ethoxylated surfactants are a broader issue for water quality. This study quantified long-chain alcohol and alkylphenol ethoxylated surfactants in Bay Area stormwater runoff, wastewater effluent, and ambient Bay water to determine concentrations and identify potential pathways of contamination. The study employed high-performance liquid chromatography coupled to high-resolution mass spectrometry to measure the rarely monitored long-chain compounds actually used in products, as opposed to the smaller degradates. Similar total ethoxylated surfactant concentrations were observed in

stormwater runoff (4,000–4,700 ng/L) and wastewater effluent (3,000–4,800 ng/L, outlier of 45,000 ng/L). Ambient Bay water contamination (non-detect–710 ng/L) was likely the result of both stormwater and wastewater inputs to the Bay. These results suggest that a broader focus including long-chain compounds and stormwater pathways may be needed to fully characterize the occurrence and impacts of ethoxylated surfactants in urban surface waters. Furthermore, addressing ethoxylated surfactants in detergents alone is likely to be insufficient to fully control water contamination. Findings inform an on-going multi-matrix RMP study of ethoxylated surfactants in the Bay and its pathways.

MORE INFORMATION

Journal Article:

Lindborg, A.R., Overdahl, K.E., Vogler, B., Lin, D., Sutton, R. and Ferguson, P.L. 2023. Assessment of Long-Chain Polyethoxylate Surfactants in Wastewater Effluent, Stormwater Runoff, and Ambient Water of San Francisco Bay, CA. ACS ES&T Water, 3(4), pp.1233-1242.



Sources, Pathways, and Loadings: Regional Watershed Modeling - Sediment

The RMP and the municipal stormwater dischargers are undertaking extensive efforts to develop and employ a dynamic watershed load simulation model to assess the impact of management actions on Bay water quality over time. A new, regional Watershed Dynamic Model (WDM) for Bay Area hydrology, sediment, and stormwater contaminant loads and trends is being developed in three phases. In Phase 1, the hydrological model was developed and calibrated (Zi et al. 2021).

Phase 2 of the modeling effort was completed in 2022 and focused on suspended sediment simulation. Modeled sediment load was calibrated and validated against observations of suspended sediment load (SSL), suspended sediment concentration (SSC), and suspended sediment particle distribution data to develop a robust estimate of annual average SSL from local tributaries to the Bay. The completed model is performing well, reproducing the timing and peaks of runoff events as well as the annual and intra-annual variation of hydrological processes and sediment loads.

This dynamic watershed sediment model is now available for the Bay Area

to estimate the total sediment and specific sediment classes (sand, silt, clay) load for the whole region and for specific watersheds.

The Phase 2 sediment modeling tool can be used to inform sediment management in our watersheds and serves as a solid basis for PCB and mercury load modeling in Phase 3 of WDM development, which will be used to simulate watershed inputs to feed into the in-Bay PCB fate model being developed by the PCB Workgroup. As a multi-use modeling platform, the WDM is being developed to be useful for other contaminants, such as contaminants of emerging concern and nutrients.

MORE INFORMATION

RMP Technical Report:

Zi T., Braud A., McKee L., Foley M. 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, CA.



Sources, Pathways, and Loadings: Regional Watershed Sediment Load Monitoring

The sediment modeling described in the previous item is hindered by the scarcity of urban stormwater flow and suspended sediment data need to calibrate the model. SFEI recently completed a study to address these data gaps by implementing a monitoring program to estimate discharge and loads of suspended sediment from four tributaries representing diverse landscape and climatic characteristics.

Monitoring was conducted from Water Year (WY) 2020 to 2023. WYs 2020 and 2021 were among the driest two consecutive WYs on record in the Bay Area. These years were followed by an approximately average WY in 2022, and then a historic wet year in WY 2023. The period between December 27, 2022, and January 17, 2023, was the second wettest consecutive 3-week period in recorded history in San Francisco. This extreme climatic variation during the monitoring period presents a good scenario from which to estimate loads using just a few years of data.

In all four watersheds, the single largest day of discharge transported significantly greater sediment loads than the entire WYs 2020 and 2021 combined, highlighting the importance of monitoring during wet years in order to accurately estimate suspended sediment loads.

Ultimately, the findings of this study will enhance the calibration and accuracy of existing simulation models and will also contribute to a better understanding of the complex interactions between urban stormwater flows and sediment transport in the region.

MORE INFORMATION

SFEI Technical Report:

Gilbreath, A., Stark, K., Pearce, S., and L. McKee. 2023. Suspended Sediment Loads Analysis of Four Creeks in the San Francisco Bay Area. SFEI Contribution #1134. San Francisco Estuary Institute, Richmond, CA.

Sediment is a lifeblood of the Bay. It serves three key functions: 1) create and maintain tidal marshes and mudflats, 2) transport nutrients and contaminants, and 3) reduce impacts from excessive human-derived nutrients in the Bay. Because of these important roles, we need a detailed understanding of sediment processes in the Bay.

A RMP report published in July 2023 provides a conceptual-level, common understanding of how fine-grained sediment (i.e., silt and finer) moves around at different scales within

the Bay to synthesize the current state of information while also identifying the key data gaps in need of more research. To do this, the report first considers overarching sediment pathways that supply sediment to the entire Estuary and then identifies more specific pathways for the baylands in the Bay, a subwatershed of the larger Estuary, between the Golden Gate and the western boundary of the Sacramento-San Joaquin Delta at Broad Slough. The visuals and narratives put forth in the report can be used as a tool to improve

current and future Bay sediment management efforts to plan for the likely effects of ongoing climate change. Content from the report can also be used to aid in communication on the state of regional sediment knowledge to help prioritize limited resources to address questions regarding sediment loading to the Bay and sediment delivery to marshes. Additionally, findings can support statewide efforts, such as those underway through the California Sediment Management Workgroup (CSMW) to evaluate the state's coastal

sediment management needs and promote regional, system-wide solutions.

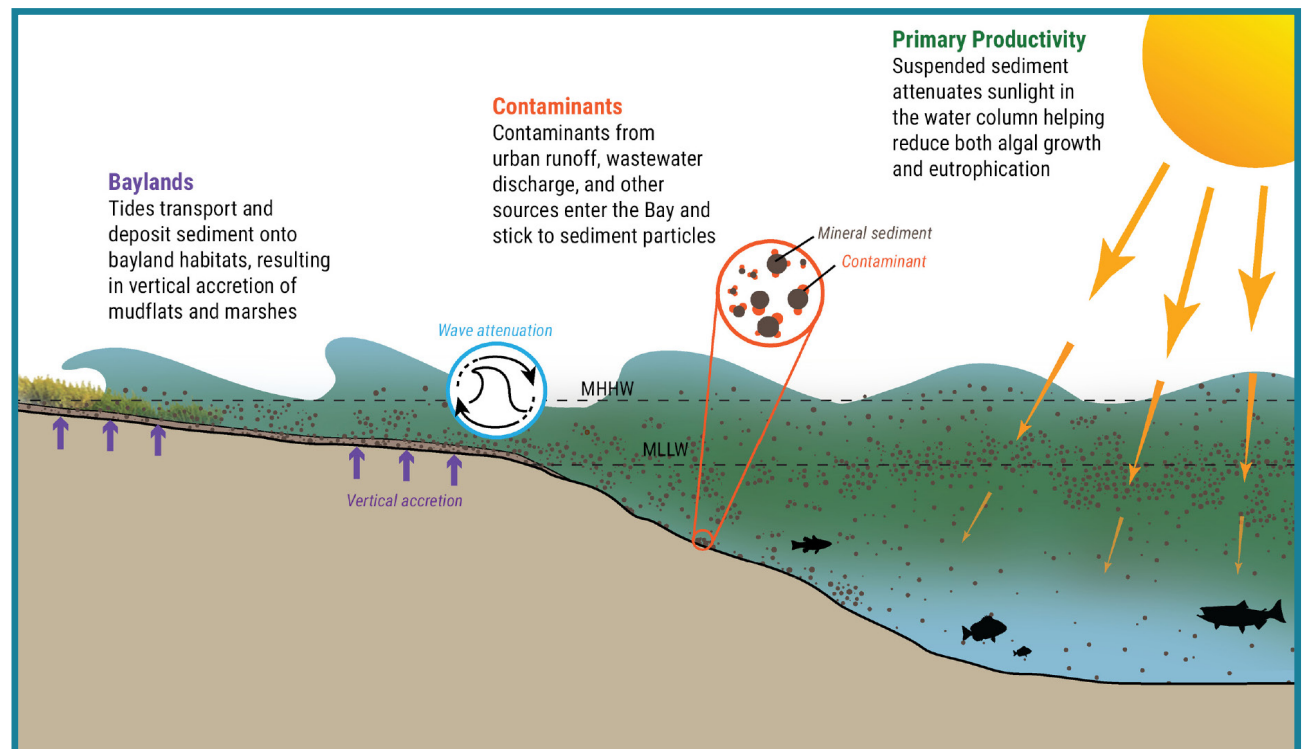
The report describes sediment processes at three scales: a conceptual understanding of open-Bay sediment processes at the Bay and subembayment scales (Chapter 2); and a conceptual understanding of sediment processes at the baylands scale (Chapter 3). Chapter 4 summarizes the key data gaps described throughout Chapters 2 and 3 and offers recommendations for next steps.

Three key considerations of sediment in the Bay include: (1) sediment builds and maintains habitat; (2) sediment transports nutrients and contaminants; (3) sediment in suspension attenuates sunlight in the water column which reduces the impacts of eutrophication.

MORE INFORMATION

SFEI Technical Report:

McKnight, K., A. Braud, S. Dusterhoff, L. Grenier, S. Shaw, J. Lowe, M. Foley, and L. McKee. 2023. Conceptual Understanding of Fine Sediment Transport in San Francisco Bay. Contribution #1114. San Francisco Estuary Institute, Richmond, CA.



9

Sediment: Continuous Suspended Sediment Monitoring in South and Lower South San Francisco Bay

Suspended sediment concentration (SSC) is of critical importance to the management of San Francisco Bay, yet has not been a focus of sustained high frequency monitoring efforts in shallow shoal and slough habitats that make up a majority of the area of the South Bay (SB) and Lower South Bay (LSB). A report published in June 2023 provides a status update for year one of a three-year collaboration between the San Francisco Bay Nutrient Management Strategy (NMS) and the RMP with the South Bay Salt Pond Restoration Project to estimate high frequency SSC throughout SB and LSB. As a part of this effort, 15-minute turbidity data from seven locations, collected as part of the NMS Moored Sensor Program, was paired with monthly discrete SSC sampling, with the goal of creating a robust turbidity-SSC calibration. An additional turbidity-specific sensor was also deployed and paired with discrete SSC sampling on the shoal near the Eden Landing Whale's Tail marsh. The report presents preliminary results from turbidity-SSC calibrations at these eight sites, which together span a range of environments (deep channel, shoal, slough) representative of the Bay. Following completion of this calibration, resource managers will be able to convert continuous high-frequency turbidity data to SSC at locations throughout SB and LSB, greatly aiding future sediment monitoring and management efforts.

MORE INFORMATION

NMS Technical Report:

Mourier, L., Volaric, M., Chelsky, A., and D. Senn. 2023. Continuous Suspended Sediment Monitoring in South and Lower South San Francisco Bay. SFEI Contribution #1135. San Francisco Estuary Institute, Richmond, CA

10

Status and Trends: Implementation of Updated Monitoring Design

Status and Trends monitoring in the RMP consists of the long-term measurement of contaminants in water, sediment, and biota and has been the core of the Program since it began in 1993. In 2002 the RMP began to implement a new sampling design for water and sediment monitoring, and shortly thereafter also evaluated and modified the design for biota monitoring.

After 20 years of implementing this basic design, the Program conducted a thoughtful and deliberate re-evaluation of RMP S&T monitoring to ensure that it is optimized to cost-effectively provide the information most needed by Bay water quality managers. The key aspect of the re-evaluation was a shift toward a primary focus on contaminants of emerging concern (CECs). The new design was completed in 2022.

Implementation of the new design began during the re-evaluation process. Some of the highlights of implementation are listed below. The new elements are being implemented in a pilot mode for three years before longer-term decisions are made.

- Wet season water (new element) - Near-field and deep Bay sampling after storms began in Water Year 2022
- Dry season water - Additional CECs included starting in 2021
- Near-field prey fish and sediment (new element) - Started in 2023
- Margins sediment - Continuation beginning in summer 2023 of work that was piloted from 2017 to 2020
- Bay sediment - Additional CECs included starting in 2023
- Marine mammals (new element) - Samples collected by The Marine Mammal Center starting in spring 2023 as part of a two-year pilot study

MORE INFORMATION

RMP Technical Report (coming soon):

Foley, M., J.A. Davis, R. Sutton, and D. Yee. In prep. A Revised Design of the Status and Trends Monitoring Element of the Regional Monitoring Program for Water Quality in San Francisco Bay. Contribution #1108. San Francisco Estuary Institute, Richmond, CA.

Reviewing sampling protocols on the 2023
Status and Trends water cruise. ►



COMING ATTRACTIONS

1 General Multi-Year Plan Updates

The RMP Multi-Year Plan is an annually updated summary of the management decisions and management that guide the Program and the studies that are being performed to address them. A major update of the Plan, including detailed plans for each RMP workgroup, will be completed in 2024.

2 CECs PFAS in Fish

Due to increasing concern about PFAS accumulation in Bay fish, in 2022 the RMP and the Water Board provided funding for analysis of 56 archived samples collected in prior years of RMP fish monitoring to expand the existing dataset. The results of the study will be reported in 2024.

3 Status and Trends Redesign Report

In 2020-2021, the RMP, with input from a panel of science advisors, conducted a process to update the design of the Status and Trends element of the Program. A report documenting the process, rationale, and details of the revised design will be available in 2024.

4 Status and Trends Results from New Design

In 2021, the RMP started to implement the revised S&T design by adding CECs to Bay water sampling. In 2022 a three-year pilot study to monitor CECs in Bay water during the wet season began. In 2023 sediment in shallow margin areas and prey fish have been sampled. Results from this initial implementation of the new design will be available in 2024.

5 PCBs Fate Model for San Leandro Bay

A major project that began in 2023 and will continue over the next several years will develop an in-Bay fate model for PCBs and other contaminants, with an initial focus on modeling PCBs in San Leandro Bay. A report on results for San Leandro Bay will be available in 2024.

6 PCBs

Passive Sampler Assessment of the Spatial Distribution of PCBs

Studies using passive samplers to assess the loading and spatial distribution of PCBs in Steinberger Slough/Redwood Creek and San Leandro Bay have been conducted to address information gaps and establish baselines for trend monitoring. A report will be available in 2024.

7 Source, Pathways, and Loadings

Watershed Load Modeling, Phase 3

The RMP is developing a Watershed Dynamic Model (WDM) in a phased, multi-year effort. The hydrology module was calibrated and completed in 2020 and served as a solid foundation for the sediment module, which was completed in 2022. Modeling of PCBs and mercury is underway, with results anticipated in 2024.

8 Sediment

Measuring Sediment Delivery to Marshes

The RMP is funding the USGS to investigate the factors controlling sediment delivery to and deposition on a South Bay tidal marsh surface. Results will be useful for prioritizing marsh restoration sites, assessing restoration actions, and understanding mechanisms of sediment delivery to and sea level rise vulnerability of marshes. A report will be available in 2024.

9 Sediment

Monitoring Sediment Flux at the Richmond Bridge

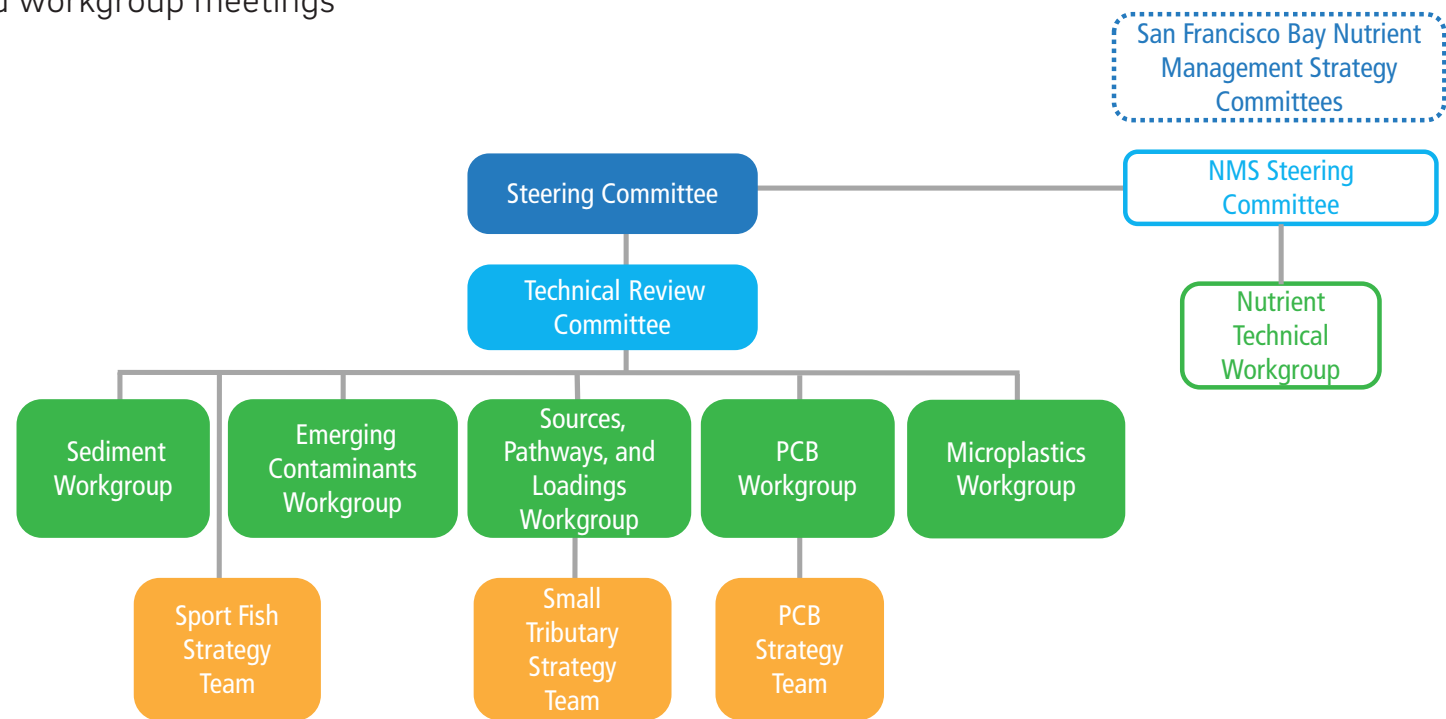
The RMP is funding the USGS to monitor suspended sediment flux at the Richmond Bridge (i.e., the boundary between San Pablo Bay and Central Bay) over the course of one water year. These findings will be useful in a range of applications, including constraining the contemporary Bay sediment budget and calibrating hydrodynamic models. The data from this project are anticipated to be available in 2025.

10 Pulse of the Bay 2024

The Pulse makes the most important information available on water quality in the Bay accessible to water quality managers, decision-makers, scientists, and the public. The next Pulse (theme to be determined) will be published at the time of the RMP Annual Meeting in October 2024.

PROGRAM OVERSIGHT

Collaboration and adaptation in the RMP are achieved through the engagement of stakeholders and scientists in frequent committee and workgroup meetings



The Steering Committee consists of representatives from discharger groups (wastewater, stormwater, dredging, industrial) and regulatory agencies (Regional Water Board and U.S. Army Corps of Engineers). The Steering Committee determines the overall budget and allocation of program funds, tracks progress, and provides direction to the Program from a manager's perspective.

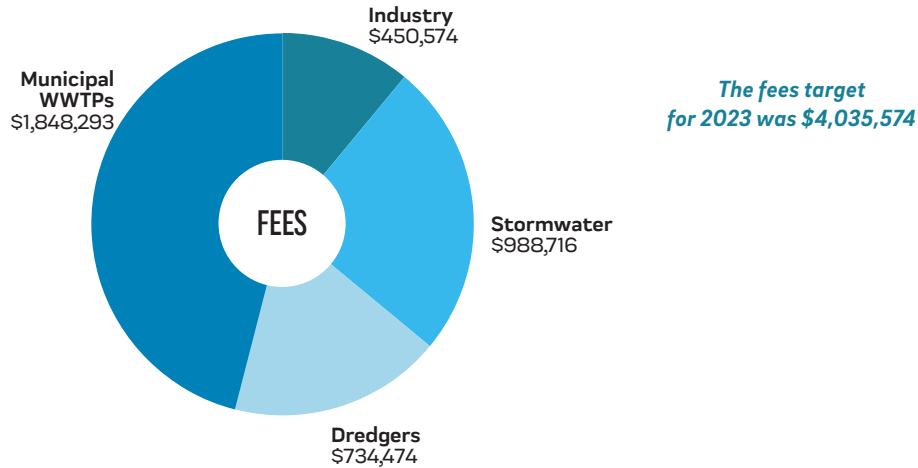
Oversight of the technical content and quality of the RMP is provided by the **Technical Review Committee** (TRC), which provides recommendations to the Steering Committee.

Workgroups report to the TRC and address the main technical subject areas covered by the RMP. The Nutrient Technical Workgroup was established as part of the committee structure of a separate effort—the Nutrient Management Strategy—and makes recommendations to the RMP committees on the use of the RMP funds that support nutrient studies. The workgroups consist of regional scientists and regulators and invited scientists recognized as authorities in the field. The workgroups directly guide planning and implementation of special studies.

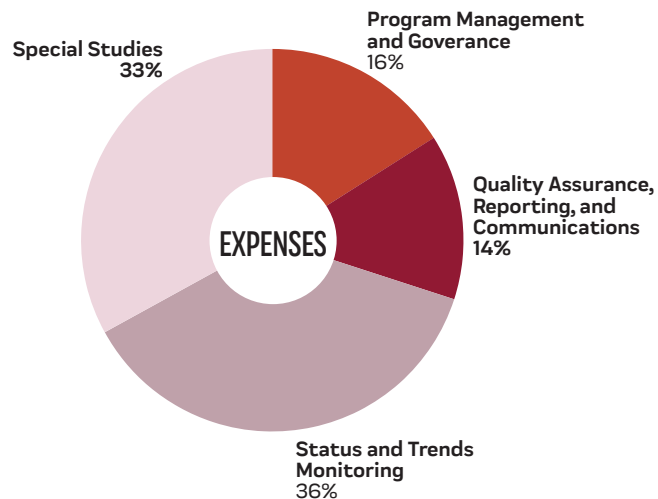
RMP strategy teams constitute one more layer of planning activity. These stakeholder groups meet as needed to develop long-term RMP study plans for addressing high priority topics.

PROGRAM MANAGEMENT

RMP FEES BY SECTOR: 2023



RMP EXPENSES: 2023



COMMUNICATIONS



Includes the *Pulse of the Bay*, *RMP Update*, Annual Meeting, Multi-Year Plan, RMP website, technical reports, journal publications, fact sheets, newsletter, oral presentations, posters, and media outreach.

PROGRAM MANAGEMENT AND GOVERNANCE

Includes internal coordination (staff management), committee and workgroup meetings, coordination with Program participants, external coordination with related groups, program planning, contract and financial management, and workgroup and peer review coordination.

DATA MANAGEMENT AND QUALITY ASSURANCE

The RMP database contains approximately 2 million records generated since the Program began in 1993. Web-based data access tools include user-defined queries, data download and printing functionality, maps of sampling locations, and visualization tools.



FEATURED PROJECT

Screening Stormwater for Contaminants of Emerging Concern

BY DR. REBECCA SUTTON, SAN FRANCISCO ESTUARY INSTITUTE

A major multi-year RMP study has revealed the critical role of urban stormwater runoff as a pathway for discharge of contaminants like PFAS, plastic additives, and chemicals derived from vehicle tires. Stormwater has long been recognized for transporting legacy contaminants like polychlorinated biphenyls (PCBs) and mercury to San Francisco Bay. Only recently has this pathway been the subject of investigations of occurrence and transport of CECs, broadly defined as un- or under-regulated chemicals that can enter the environment and harm people or wildlife. Within the global scientific community, the RMP is at the forefront of advancing this new understanding of stormwater. In the current study, the RMP developed a uniquely comprehensive dataset demonstrating the potential of this pathway to transport CECs into receiving waters and degrade water quality.

A key clue that stormwater might be an important pathway for emerging contaminants came from the findings of an exploratory study of Bay water samples collected in 2016 (Overdahl et al., 2021). Using a novel technique called nontarget analysis, which screens for contaminants without a pre-defined list of chemicals of interest, scientists observed the broadest array of unique compounds

in water from a stormwater-influenced site relative to other locations within San Francisco Bay. To address this finding, we brought together RMP scientists, stakeholders, and leading experts on both CECs and stormwater monitoring to craft a study to provide screening-level data (occurrence and concentration) and evaluate the role of stormwater as a transport pathway for a suite of contaminants identified as important for the Bay. This monitoring effort spanned four wet seasons (water years 2019-2022), sampled both urban and reference (minimally developed) sites during storm events, and analyzed five broad classes of contaminants: PFAS, organophosphate esters, bisphenols, ethoxylated surfactants, and tire-derived compounds.

Overall, the findings demonstrated that urban stormwater runoff contains a broad array of emerging contaminants, with concentrations often similar to those found in a more frequently studied pathway, municipal wastewater effluent. We observed wide concentration ranges for many contaminants, indicating the need for a significant amount of monitoring data to inform models that estimate loads to the Bay. Preliminary interpretation also revealed major knowledge gaps

Highlights

- Many contaminants of emerging concern (CECs) are present in urban stormwater runoff and receiving waters
- Stormwater and wastewater are both important pathways for discharge of CECs to San Francisco Bay
- Relatively little is known about outdoor sources of CECs to stormwater, making effective management challenging
- The RMP has launched next steps to a) design innovative remote sampling technologies to increase sampling capacity and reduce cost, and b) obtain additional stormwater flow and contaminant concentration data to estimate loads and inform management actions

regarding sources (e.g., commercial products and their uses) that might be driving the presence of individual contaminants in urban stormwater, limiting effective management. Here, we summarize high-level findings and future RMP work designed to further elucidate the occurrence, transport, and impact of CECs in stormwater.



Collecting a stormwater sample in Visitacion Valley in San Francisco, December 2022.

PFAS

Per- and polyfluoroalkyl substances (PFAS) are a high priority for the RMP and state and federal regulatory agencies. These fluorine-rich specialty chemicals are widely used in consumer and industrial products. Also known as “forever chemicals,” their alarming persistence in the environment has led to contamination worldwide. Perfluorooctanoic acid (PFOA) and perfluorooctanesulfonate (PFOS), the two most well-studied PFAS, are bioaccumulative and toxic to people and wildlife, widely observed in environmental matrices, and have been phased out of production in the US and many other countries. Unfortunately, alternative PFAS have ongoing (and in some cases growing) use in products and are known or expected to present similar toxicity concerns. The RMP has been monitoring PFAS across Bay matrices for over a decade (Sedlak et al., 2018), and is working with local wastewater and stormwater agencies to build information on PFAS in these pathways.

Our multi-year RMP screening study revealed widespread detections of PFAS in urban stormwater runoff, with multiple members of this class observed at every single urban site we visited. The dominant PFAS we observed include perfluorohexanoic acid (PFHxA), PFOS, and PFOA. These and other commonly monitored PFAS were observed in stormwater at similar concentrations to those observed in municipal wastewater effluent via an ongoing SFEI study funded by the Bay Area Clean Water Agencies (Mendez et al., 2021). These findings confirmed our hypothesis that stormwater is an important pathway for PFAS and merits additional efforts to determine concentrations and loads to the Bay.

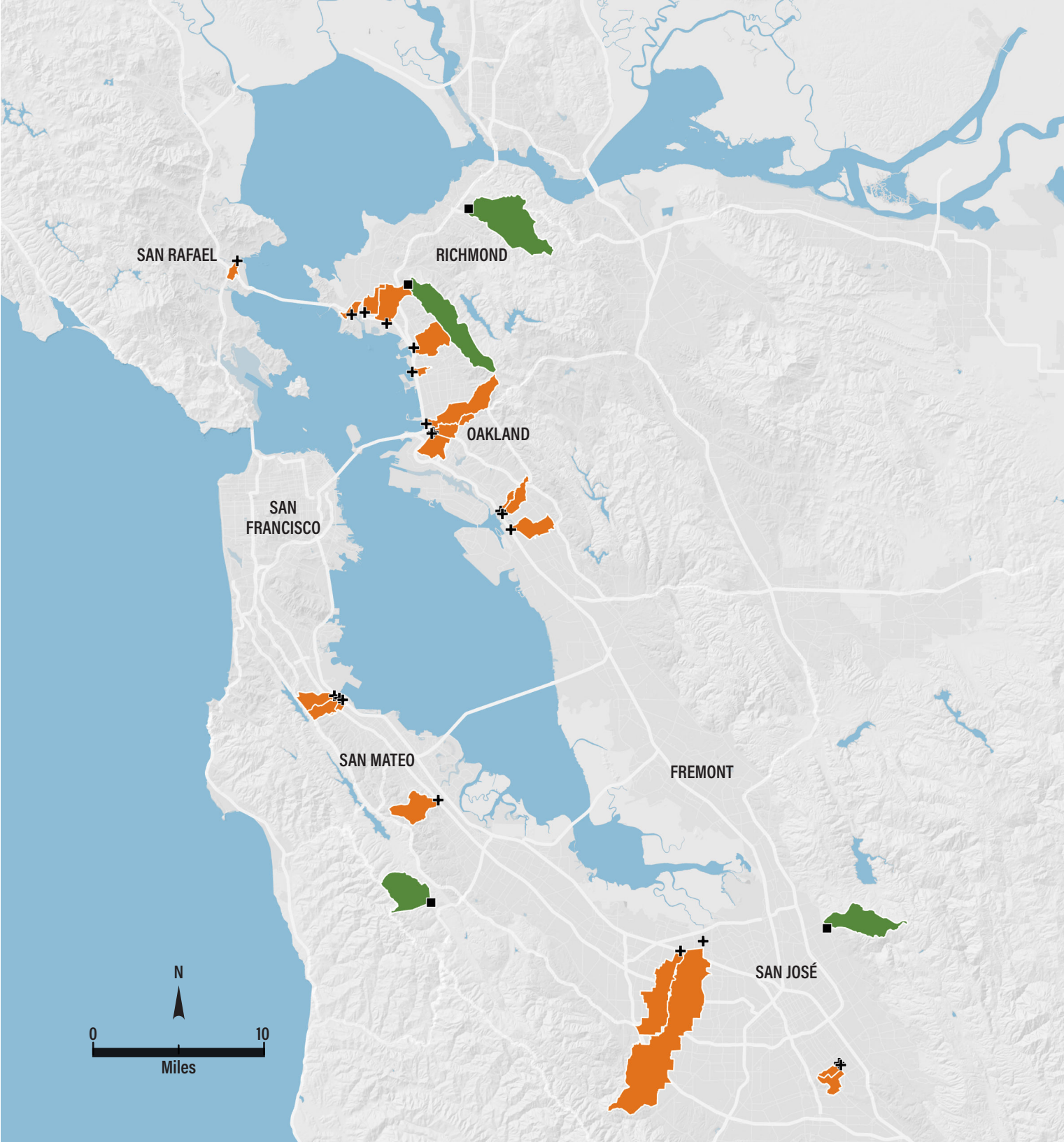
Worldwide, efforts to characterize concentrations of PFAS in urban stormwater runoff and identify and manage relevant sources in the watershed have lagged behind similar work in municipal wastewater. A comprehensive catalog of potential outdoor PFAS uses relevant to stormwater does not exist, limiting effective regulatory management of PFAS. Some outdoor sources include exterior and road marking paints; roofing, siding, and other construction materials; solar panels and related equipment; automotive finishes and cleaners; and outdoor textiles. In contrast, significantly more work has been done to identify and manage PFAS sources contributing to concentrations and loads in wastewater. California has already initiated PFAS bans for products such as cosmetics, clothing, and paper-based food packaging.

Comparison of dominant PFAS observed in urban stormwater runoff and municipal wastewater effluent in the San Francisco Bay Area. Wastewater data from study described by Mendez et al. (2021).

PFAS	Stormwater Median (Range) [ng/L]	Wastewater Median (Range) [ng/L]
PFHxA	10 (4 - 180)	13 (<MDL - 30)
PFOA	7.7 (3 - 110)	5 (3 - 12)
PFOS	8.5 (<MDL - 81)	5 (<MDL - 13)



Stormwater flowing in Visitacion Valley in San Francisco, December 2022.



SAMPLING LOCATIONS

- + Urban Stormwater
- Reference

WATERSHED

- Urban Stormwater
- Reference

Stormwater sampling site information:

The multi-year RMP screening study examined stormwater samples from 25 watersheds. Twenty-one urban stormwater sites were downstream of watersheds with 69-100% highly developed land uses (average 93%) and drainage area 0.66–50 km². Four contrasting reference sites were downstream of minimally developed watersheds with more than 90% low impervious intensity land use and drainage area 12–23 km². Most sites were sampled once over the course of the study, while a few were sampled up to three times.



Stormwater sampling in Belmont Creek, in Belmont.

Organophosphate Esters

Organophosphate esters (OPEs) are widely used in plastics, as additive flame retardants and for other functional purposes in plastics. Use as flame retardants increased dramatically following restrictions on polybrominated diphenyl ether (PBDE) flame retardants in the 2000s. Organophosphate esters are now recognized as regrettable substitutes for PBDEs. Sources of OPEs particularly relevant to stormwater include vehicle components and fluids and release to the environment via exhaust; building insulation, paint, roof coatings, and other construction materials; and outdoor textiles. Observation of some OPEs in the Bay at levels well above toxicity thresholds during previous studies (Shimabuku et al., 2022; Sutton et al., 2019) has led the RMP to classify this group of contaminants as a high concern.

In the RMP stormwater screening study, 29 of 36 individual OPE compounds were observed in all or nearly all urban stormwater samples. Three compounds were observed at concentrations as high as thousands of nanograms per liter (up to 9,300 ng/L): two chlorinated OPEs (TDCIPP and TCIPP) widely

used as flame retardants, and another non-chlorinated OPE (TBOEP) more commonly used in paints, coatings, floor polishes, vinyl resins, and plastics. These compounds drive the overall RMP risk evaluation for the Bay. In addition, we observed several members of two newly identified subclasses of flame retardant OPEs in urban stormwater (isopropylated & tert-butylated triphenylphosphate esters), emphasizing the ubiquitous environmental presence of these compounds.

These results indicated urban stormwater runoff is an important pathway for OPEs to the Bay. Prior work suggested municipal wastewater is also important (Sutton et al., 2019); a RMP special study to characterize this pathway will begin next year (2024). Meanwhile, multiple California regulations intended to reduce unnecessary and ineffective use of flame retardants are likely limiting incorporation of OPEs in many consumer goods. However, many other uses of OPEs have not been assessed or addressed despite the threat to aquatic wildlife from this large chemical class, making effective management challenging.

Bisphenols

Bisphenol A (BPA) is one of the most widely known and well-studied plastic ingredients, as it can disrupt the endocrine system and impact reproduction, development, and a variety of other endpoints. BPA is produced and used in vast quantities worldwide—especially in polycarbonate plastics and as a polymer additive. BPA is also used in the epoxy resin linings that are found in metal-based food and beverage cans, as well as in the production of flame retardants and vehicle tires; as reactants in thermal paper products; and as additives in textiles and paints. Recently, some manufacturers have begun using alternative bisphenol compounds, such as bisphenol F (BPF) and bisphenol S (BPS), which are less well-studied but likely have similar toxic properties to BPA. These uses of bisphenols have led to widespread bisphenol detections in the environment and wildlife.

BPA was observed in every single urban stormwater sample in the RMP screening study. The highest observed concentration was 740 nanograms per liter, though the median concentration was about half that observed in a recently completed RMP

study on bisphenols in treated wastewater effluent (Mendez et al., 2022). BPF was also observed in nearly all samples, while BPS was found in just over half the samples. Of the remaining 14 bisphenols included in our analysis, only one was detected, and this detection occurred at a single site. Overall, median stormwater values suggest stormwater is an important pathway transporting bisphenols into the Bay, though concentrations were lower overall than those observed in Bay Area wastewater effluents.

BPA has been the subject of multiple bans for use in different consumer goods, primarily to protect human health. These bans have predominantly targeted plastic products with food contact, including baby bottles, sippy cups, and sports bottles. Many companies now market products as “BPA-free.” Unfortunately, such products may contain other bisphenols, which can be considered regrettable substitutes for BPA. Without a fuller picture of the potential sources of bisphenols to stormwater as well as wastewater, it is difficult to effectively address the contamination of these pathways and our Bay.

Comparison of dominant bisphenols observed in urban stormwater runoff and municipal wastewater effluent in the San Francisco Bay Area. Wastewater data from Mendez et al. (2022).

Bisphenols	Stormwater Median (Range) [ng/L]	Wastewater Median (Range) [ng/L]
BPA	18 (1.7 – 740)	41 (1.6 – 62)
BPF	6.3 (<MDL – 96)	30 (2.6 – 128)
BPS	1.4 (<MDL – 20)	24 (<MDL – 55)



Stormwater sampling at a green infrastructure installation in the Mission Bay neighborhood of San Francisco.



Stormwater sampling at a green infrastructure installation in the Mission Bay neighborhood of San Francisco.

Ethoxylated Surfactants

Ethoxylated surfactants are detergent-like compounds with broad uses in consumer and industrial products. Sources to stormwater include outdoor use in vehicle tires and automotive cleaners, lubricants, and other fluids; additives in concrete, paint, and other construction materials; as well as uses in cleaning products, pesticides, plastics, and many other items. The 2016 RMP study that leveraged nontarget analysis to examine known, unexpected, and unknown chemicals in Bay water identified many ethoxylated surfactants with strong analytical responses (a relative indication of concentration) in a stormwater-influenced site within the Bay (Overdahl et al., 2021). These results led to renewed interest in ethoxylated surfactants, including both alkylphenol and alcohol ethoxylates.

The current RMP screening study indicated ethoxylated surfactants are ubiquitous in urban stormwater (Lindborg et al., 2023). A unique aspect of the RMP effort was the characterization of the larger surfactant compounds actually used in consumer products, as most other studies of ethoxylated surfactants only examine smaller, related compounds that form after biodegradation. We observed that concentrations of the larger compounds rivaled those of the more commonly analyzed degradates, suggesting that

narrow monitoring efforts may exclude important contaminants and underestimate total risk.

Meanwhile, state and federal efforts at source control primarily apply to products with uses that result in indoor down-the-drain disposal that directs chemicals to municipal wastewater treatment plants and, therefore, are not expected to reduce their presence in stormwater. A nationwide voluntary phase-out of one subclass—nonylphenol ethoxylates—in consumer laundry detergents has already begun. California’s Department of Toxic Substances Control (DTSC) has proposed regulating this specific subclass in all laundry detergent due to concern about impacts to aquatic organisms. If regulated, detergent manufacturers would be required to identify and evaluate safer alternatives. The California Air Resources Board has also banned alkylphenol ethoxylates in a variety of other cleaning products. In contrast, in Europe alkylphenol ethoxylates are listed as Substances of Very High Concern, and restrictions are in place for most products and uses.

The stormwater monitoring reported here is part of a larger, on-going multi-matrix study on ethoxylated surfactants in the Bay. Altogether, the data will inform placement of ethoxylated surfactants in the RMP’s tiered risk-based framework for CECs and indicate whether additional monitoring should be prioritized.

Tire-derived Contaminants

In December 2020, RMP collaborators in the State of Washington announced the findings of a decades-long effort to identify the cause of water quality linked coho salmon deaths in Puget Sound streams (Tian et al., 2021). The causative contaminant, 6PPD-quinone (6PPDQ), is a highly toxic transformation product of the ubiquitously used tire preservative 6PPD. When it rains, 6PPDQ can wash into streams and the Bay along with the tire wear particles that form during driving due to friction between tires and the road. Coho salmon no longer reside in San Francisco Bay and its streams, but they are being restored to coastal streams from Santa Cruz to Sonoma County. They currently populate the Klamath, Smith, and Eel Rivers further north. Recent research indicates steelhead, a related salmonid that is found in the Bay and its tributaries, is also sensitive to 6PPDQ (Brinkmann et al., 2022). Little is currently known about the toxicity of 6PPDQ to other species, or its potential for adverse sublethal effects in other aquatic organisms.

The multi-year RMP screening study included 6PPDQ and five other chemicals associated with vehicle tires, such as rubber vulcanization accelerators and related transformation products and a rubber hardener. All were observed in urban stormwater runoff, with levels of 6PPDQ approaching or exceeding available toxicity

thresholds at several sites. Statistical examination indicated that concentrations of most tire-derived contaminants were positively correlated with each other, consistent with tire rubber as their primary product source for runoff.

In August, California's DTSC became the first government agency in the world to regulate the chemical content of vehicle tires to protect salmon. DTSC is requiring tire manufacturers to identify safer alternatives to the tire preservative 6PPD, the "parent compound" of 6PPDQ, which is used in the majority of tires worldwide. Preliminary monitoring data collected as part of this RMP study were essential to establishing the DTSC regulation for California.

The RMP screening study clearly demonstrated that several tire-derived contaminants beyond 6PPDQ are ubiquitous in stormwater and also present at relatively high concentrations. For example, the median concentration of 1,3-diphenylguanidine (DPG), a rubber vulcanization agent, was 1,200 nanograms per liter. Tire-derived compounds merit further investigation, as limited or no toxicity information is available. The results emphasized the importance of managing tires as a key source of chemical contamination with unknown toxicity implications to stormwater-impacted receiving waters.



Stormwater sampling in Belmont Creek, in Belmont.

What's Next?

The findings of this major, multi-year monitoring effort clearly demonstrate that urban stormwater runoff is an important pathway for discharge of a broad range of emerging contaminants to San Francisco Bay. The RMP's unique dataset, encompassing hundreds of contaminants of interest, provides a novel glimpse of the staggering array of chemicals that can be washed from outdoor surfaces in our cities and into the Bay when it rains.

Essential work to build on this knowledge has already begun. To better understand contaminant transport and fate in the Bay, the RMP launched an additional pilot effort to monitor Bay water following storms, to ascertain the impact of stormwater flows on Bay water quality. Preliminary results to date indicate the strong influence of stormwater on Bay contaminant concentrations during the wet season. Monitoring will be completed in 2024.

In parallel, RMP scientists and engineers have begun designing innovative remote samplers that will reduce the need for intensive manual sampling during storms, and thus both increase capacity and reduce cost for stormwater monitoring. Trial deployments are expected to begin with the coming winter rains (2023-2024). Though key technological challenges remain, the initial designs show great promise, and academics and government agencies are actively seeking our support to disseminate this technology.

At a higher level, the RMP has initiated development of an approach to monitor CECs in urban runoff that will integrate conceptual and computational modeling to cost-effectively answer management questions, including estimating contaminant loads to the Bay. Moving forward, we anticipate a continuing focus on characterizing CECs in stormwater, an under-explored contaminant pathway in the Bay Area and globally. With each new study we will further build the knowledge needed to inform effective management and protect Bay water quality. §

References

- Brinkmann, M., Montgomery, D., Selinger, S., Miller, J. G. P., Stock, E., Alcaraz, A. J., Challis, J. K., Weber, L., Janz, D., Hecker, M., & Wiseman, S. (2022). Acute Toxicity of the Tire Rubber-Derived Chemical 6PPD-quinone to Four Fishes of Commercial, Cultural, and Ecological Importance. *Environmental Science & Technology Letters*, 9(4), 333–338. <https://doi.org/10.1021/acs.estlett.2c00050>
- Lindborg, A. R., Overdahl, K. E., Vogler, B., Lin, D., Sutton, R., & Ferguson, P. L. (2023). Assessment of Long-Chain Polyethoxylate Surfactants in Wastewater Effluent, Stormwater Runoff, and Ambient Water of San Francisco Bay, CA. *ACS ES&T Water*, 3(4), 1233–1242. <https://doi.org/10.1021/acsestwater.3c00024>
- Mendez, M., Lin, D., Wong, A., Yee, D., & Sutton, R. (2021). Study of Per- and Polyfluoroalkyl Substances in Bay Area POTWs Phase 1 Memo (SFEI Contribution No. 1145). San Francisco Estuary Institute.
- Mendez, M., Miller, E., Liu, J., Chen, D., & Sutton, R. (2022). Bisphenols in San Francisco Bay: Wastewater, Stormwater, and Margin Sediment Monitoring (SFEI Contribution No. 1093). San Francisco Estuary Institute. <https://www.sfei.org/documents/bisphenols-san-francisco-bay-wastewater-stormwater-and-margin-sediment-monitoring>
- Overdahl, K. E., Sutton, R., Sun, J., DeStefano, N. J., Getzinger, G. J., & Ferguson, P. L. (2021). Assessment of emerging polar organic pollutants linked to contaminant pathways within an urban estuary using non-targeted analysis. *Environmental Science: Processes & Impacts*, 23, 429–445. <https://doi.org/10.1039/D0EM00463D>
- Sedlak, M. D., Sutton, R., Wong, A., & Lin, D. (2018). Per and Polyfluoroalkyl Substances (PFASs) in San Francisco Bay: Synthesis and Strategy. SFEI Contribution No. 867. San Francisco Estuary Institute. https://www.sfei.org/sites/default/files/biblio_files/PFAS%20Synthesis%20and%20Strategy.pdf
- Shimabuku, I., Chen, D., Wu, Y., Miller, E., Sun, J., & Sutton, R. (2022). Occurrence and risk assessment of organophosphate esters and bisphenols in San Francisco Bay, California, USA. *Science of The Total Environment*, 813, 152287. <https://doi.org/10.1016/j.scitotenv.2021.152287>
- Sutton, R., Chen, D., Sun, J., Greig, D. J., & Wu, Y. (2019). Characterization of brominated, chlorinated, and phosphate flame retardants in San Francisco Bay, an urban estuary. *Science of The Total Environment*, 652, 212–223. <https://doi.org/10.1016/j.scitotenv.2018.10.096>
- Tian, Z., Zhao, H., Peter, K. T., Gonzalez, M., Wetzel, J., Wu, C., Hu, X., Prat, J., Mudrock, E., Hettinger, R., Cortina, A. E., Biswas, R. G., Kock, F. V. C., Soong, R., Jenne, A., Du, B., Hou, F., He, H., Lundeen, R., ... Kolodziej, E. P. (2021). A ubiquitous tire rubber-derived chemical induces acute mortality in coho salmon. *Science*, 371(6525), 185–189. <https://doi.org/10.1126/science.abd6951>

Photographs by David Peterson at Arroyo Corte Madera del Presidio in Marin County (top left) and Don Yee at Lower Coyote Creek in Marin County (others).



RMP scientists and engineers are designing innovative remote samplers that will reduce the need for labor-intensive manual sampling during storms, increasing capacity and reducing cost for monitoring

The Pulse

A wide-angle photograph of a crowded beach on a sunny day. In the foreground, people are sitting on the sand, some under large beach umbrellas. The water is clear and blue, with many people swimming and wading. In the background, the iconic Golden Gate Bridge spans the water, with its red towers and suspension cables clearly visible. The sky is a clear, bright blue. The overall scene depicts a popular recreational spot with a significant landmark in the distance.



Bálan, S. A.; Andrews, D. Q.; Blum, A.; Diamond, M. L.; Fernández, S. Rojello; Harriman, E.; Lindstrom, A. B.; Reade, A.; Richter, L.; Sutton, R.; et al. 2023. Optimizing Chemicals Management in the United States and Canada through the Essential-Use Approach. *Environmental Science & Technology* 57 (4).

Lin, D.; Hamilton, C.; Hobbs, J.; Miller, E.; Sutton, R. 2023. Triclosan and Methyl Triclosan in Prey Fish in a Wastewater-influenced Estuary. *Environmental Toxicology and Chemistry*. SFEI Contribution No. 1112.

Shimabuku, I.; Chen, D.; Wu, Y.; Miller, E.; Sun, J.; Sutton, R. 2022. Occurrence and risk assessment of organophosphate esters and bisphenols in San Francisco Bay, California, USA. *Science of the Total Environment* 813. SFEI Contribution No. 982.

Wang, M.; Kinyua, J.; Jiang, T.; Sedlak, M.; McKee, L. J.; Fadness, R.; Sutton, R.; Park, J. - S. 2022. Suspect Screening and Chemical Profile Analysis of Storm-Water Runoff Following 2017 Wildfires in Northern California. Environmental Toxicology and Chemistry. SFEI Contribution No. 1089.

Chang, D.; Richardot, W.; Miller, E.; Dodder, N.; Sedlak, M.; Hoh, E.; Sutton, R. 2021. Framework for nontargeted investigation of contaminants released by wildfires into stormwater runoff: Case study in the northern San Francisco Bay area. Integrated Environmental Assessment and Management. SFEI Contribution No. 1044.

Klasios, N.; De Frond, H.; Miller, E.; Sedlak, M.; Rochman, C. M. 2021. Microplastics and other anthropogenic particles are prevalent in mussels from San Francisco Bay, and show no correlation with PAHs. *Environmental Pollution* 271.

Overdahl, K. E.; Sutton, R.; Sun, J.; DeStefano, N. J.; Getzinger, G. J.; P. Ferguson, L. 2021. Assessment of emerging polar organic pollutants linked to contaminant pathways within an urban estuary using non-targeted analysis. SFEI Contribution No. 1107. Environmental Sciences: Processes and Impacts.

Zhu, X.; Munno, K.; Grbic, J.; Werbowski, L. M.; Bikker, J.; Ho, A.; Guo, E.; Sedlak, M.; Sutton, R.; Box, C.; et al. 2021. Holistic Assessment of Microplastics and Other Anthropogenic Microdebris in an Urban Bay Sheds Light on Their Sources and Fate. *Environmental Science and Technology Water*. SFEI Contribution No. 1060.

Program Planning Documents

Foley, M.; Davis, J.; Yee, D. 2023. Multi-Year Plan 2023. SFEI Contribution No. 1096. San Francisco Estuary Institute: Richmond, California.

Applied Marine Sciences. 2022. 2021 RMP Water Cruise Report. SFEI Contribution No. 1098. Applied Marine Sciences: Livermore, CA.

Foley, M. 2022. 2022 RMP Multi-Year Plan. SFEI Contribution No. 1058. San Francisco Estuary Institute: Richmond, CA.

Fact Sheets, Selected Posters and Presentations

Find links to all presentations from the 2022 RMP Annual Meeting on the 2022 Annual Meeting webpage. <https://www.sfei.org/events/2022-rmp-annual-meeting>

Moran, K.; Askevold, R. 2022. Microplastics from Tire Particles in San Francisco Bay Factsheet. SFEI Contribution No. 1074. San Francisco Estuary Institute: Richmond, CA.

Dusterhoff, S.; McKnight, K.; Grenier, L.; Kauffman, N. 2021. Sediment for Survival fact sheet.

Technical Reports

Gilbreath, A. N.; Stark, K.; Pearce, S.; McKee, L. 2023. Suspended Sediment Loads Analysis of Four Creeks in the San Francisco Bay Area. SFEI Contribution No. 1134. San Francisco Estuary Institute: Richmond, CA.

McKnight, K.; Braud, A.; Dusterhoff, S.; Grenier, L.; Shaw, S.; Lowe, J.; Foley, M.; McKee, L. 2023. Conceptual Understanding of Fine Sediment Transport in San Francisco Bay. SFEI Contribution No. 1114. San Francisco Estuary Institute: Richmond, CA.

Moran, K.; Sutton, R. 2023. Tire Wear: Emissions Estimates and Market Insights to Inform Monitoring Design. SFEI Contribution No. 1109. San Francisco Estuary Institute: Richmond, CA.

Yee, D.; Wong, A. 2023. Re-evaluation of the Floating Percentile Method for Deriving Dredged Sediment Screening Guidelines. SFEI Contribution No. 1143. San Francisco Estuary Institute: Richmond, California.

Gilbreath, A.; Davis, J. 2022. Priority margin unit stormwater monitoring to support load estimates of PCBs into San Leandro Bay and the Emeryville Crescent. SFEI Contribution No. 1088. San Francisco Estuary Institute: Richmond, CA.

Jones, C.; Davis, J.; Yee, D. 2022. Strategy for In-Bay Fate Modeling to Support Contaminant and Sediment Management in San Francisco Bay. SFEI Contribution No. 1090. San Francisco Estuary Institute: Richmond, California.

McKee, L.; Gilbreath, A.; Sabin, L. 2022. Small Tributaries Pollutants of Concern Reconnaissance Monitoring: Application of Storm-event Loads and Yields-Based and Congener-Based PCB Site Prioritization Methodologies. SFEI Contribution No. 1067.

Mendez, M.; Trinh, M.; Miller, E.; Lin, D.; Sutton, R. 2022. PFAS in San Francisco Bay Water. SFEI Contribution No. 1094. San Francisco Estuary Institute: Richmond, CA.

Mendez, M.; Grosso, C.; Lin, D. 2022. Summary and Evaluation of Bioaccumulation Tests for Total Polychlorinated Biphenyls (PCBs) Conducted by San Francisco Bay Dredging Projects. SFEI Contribution No. 1092. San Francisco Estuary Institute: Richmond, California.

Sutton, R.; Lin, D. 2022. CECs in California's Ambient Aquatic Ecosystems: Occurrence and Risk Screening of Key Classes. SFEI Contribution No. 1066. Aquatic Science Center: Richmond, CA.

Zi, T.; Braud, A.; McKee, L. J.; Foley, M. 2022. San Francisco Bay Watershed Dynamic Model (WDM) Progress Report, Phase 2. SFEI Contribution No. 1091. San Francisco Estuary Institute: Richmond, California.

Dusterhoff, S.; McKnight, K.; Grenier, L.; Kauffman, N. 2021. Sediment for Survival: A Strategy for the Resilience of Bay Wetlands in the Lower San Francisco Estuary. SFEI Contribution No. 1015. San Francisco Estuary Institute: Richmond, CA.

Mendez, M.; Lin, D.; Sutton, R. 2021. Study of Per- and Polyfluoroalkyl Substances in Bay Area POTWs: Phase 1, Sampling and Analysis Plan. SFEI Contribution No. 1020. San Francisco Estuary Institute: Richmond, CA.

Moran, K.; Miller, E.; Mendez, M.; Moore, S.; Gilbreath, A.; Sutton, R.; Lin, D. 2021. A Synthesis of Microplastic Sources and Pathways to Urban Runoff. SFEI Contribution No. 1049. San Francisco Estuary Institute: Richmond, CA.





Program **IMPACT**

◀ In transit on the 2023 Status
and Trends sediment cruise

The **IMPACT** of the RMP on Management Decisions

Informing High Stakes Decisions

Billions of dollars are at stake in decisions regarding activities that are directly intended to protect Bay water quality. The region has made huge investments to build and operate the infrastructure to collect and treat the region's sewage and industrial wastewater, and continued investment at a similar scale will be needed to maintain, upgrade, and operate this infrastructure to serve a growing Bay Area population. The region has spent and will continue to spend comparably large sums to manage contaminated soil and sediment in Bay watersheds, to manage stormwater, and to establish green infrastructure in our cities to capture stormwater and minimize its adverse water quality impacts on the Bay. Large investments have been and will be made to manage contaminated sediment in the Bay: at sites identified for cleanup, for dredging to maintain channels for commercial and recreational vessels, and for infrastructure to support using dredged sediment to restore wetlands and make the Bay shoreline more resilient to rising sea level.





Billions more are riding on decisions regarding activities that influence Bay water quality as unintentional side-effects.

Commercial product formulation and usage (including pesticides, pharmaceuticals, personal care products, electrical equipment, home furnishings, automobile components, and many, many others), sediment management, water supply management, energy production, and habitat restoration and management are all immense and essential enterprises that have a tremendous influence on Bay water quality.

More than money is at stake. Protecting the health of people who eat fish and shellfish from the Bay is one of the primary objectives of water quality managers. Cleanup plans for many contaminants are driven by this objective, as are decisions regarding advisories to promote safe consumption of fish from the Bay. Cleanup plans also aim to protect the health of fish, wildlife, and all of the aquatic species that live in the Bay.

The goal of the RMP is to collect data and communicate information about Bay water quality in support of all of these management decisions. The \$4 million annual budget for the RMP is used judiciously so that these decisions on Bay water quality are informed by sound science.

◀ View of San Francisco from the Status and Trends water cruise, 2023.

Regulatory Policies Informed by the RMP

Management of pollutant discharges to the Bay: wastewater, stormwater, dredged material

Regional Water Board, US Environmental Protection Agency

303(d) Listings

Total Maximum Daily Load Control Plans (TMDLs)

- San Francisco Bay Mercury TMDL
- Guadalupe River Mercury TMDL
- San Francisco Bay PCBs TMDL
- North Bay Selenium TMDL
- Suisun Marsh TMDL for Dissolved Oxygen and Mercury

Permits

- National Pollutant Discharge Elimination System (NPDES) wastewater discharge permit provisions
- Municipal Regional Stormwater Permit - Load reductions, green infrastructure planning
- Mercury and PCBs Watershed Permit for Municipal and Industrial Wastewater
- Nutrient Watershed Permit for Municipal Wastewater

Criteria

- Site-specific objectives and implementation plans for copper and cyanide
- Nutrient numeric endpoint framework (under development)

Contaminant of Emerging Concern (CEC) Action Plans

Commercial product formulation and usage

California Department of Pesticide Regulation, Department of Toxic Substances Control, others

- State legislative bans: microbeads, PBDEs, copper in brake pads
- State flammability standards for furniture and building materials: flame retardants
- State pesticide regulations: e.g., pyrethroids
- State Safer Consumer Products regulations
- State product label changes: fipronil
- Federal legislative bans: PCBs, microbeads
- Federal pesticide regulations: DDT, chlordane, dieldrin, diazinon, and chlorpyrifos
- County and local drug take-back ordinances and programs

Dredging and dredged material management

US Army Corps of Engineers, San Francisco Regional Water Board, San Francisco Bay Conservation and Development Commission, US Environmental Protection Agency, and others

- Dredging and dredged material disposal permits through the Dredged Material Management Office
- Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region (LTMS)
- Essential Fish Habitat Agreement for Maintenance Dredging Conducted Under the LTMS Program
- Regional restoration plans

Public health protection

California Office of Environmental Health Hazard Assessment

- Fish consumption advice and communication

▼ Cargo ship on the Bay.



RMP Impact Summary

Municipal Wastewater Dischargers

DECISIONS INFORMED BY THE RMP

- **Are treatment plant modifications or upgrades, or source reduction activities needed?**
 - **Which contaminants need to be reduced in municipal wastewater?**
Examples of contaminants currently under consideration for reductions are nutrients, the pesticides fipronil and imidacloprid, and other contaminants of emerging concern.
 - **At which treatment plants are the reductions needed?**
Different segments of the Bay vary greatly in their general characteristics, including in some cases their sensitivity to additional contaminant loads. The need for load reductions may therefore vary in different segments of the Bay.
 - **How much of a reduction is needed?**
The goal of TMDLs and other control plans is to reduce concentrations in the Bay to levels that do not significantly impact beneficial uses. This requires a solid understanding of impairment and contaminant cycling in the Bay.
 - **What is the effect of the reductions or modifications on Bay water quality?**
Monitoring is essential in demonstrating that load reduction efforts achieve the desired improvement in beneficial use attainment. Monitoring is needed to ensure that treatment plant modifications (e.g., implementation of reverse osmosis for water reuse) have no adverse impacts on beneficial uses.
-
- **Are actions needed for other pathways to reduce loads and impairment from contaminants found in municipal wastewater?** A holistic understanding of the relative importance of loads for all pathways is needed to optimize overall load reduction efforts.

REGULATIONS ADDRESSED

NPDES Permits

Mercury TMDL

PCBs TMDL

North Bay Selenium TMDL

Copper Site-Specific Objective (SSO) Implementation Plan

Nutrient Watershed Permit

Mercury and PCBs Watershed Permit

CEC Action Plans

Cyanide SSO Implementation Plan

Department of Toxic Substances Control (DTSC) Safer Consumer Product Regulations

Department of Pesticide Regulation (DPR) state pesticide regulations

USEPA Federal Insecticide, Fungicide, and Rodenticide Act

RMP Impact Summary

Municipal Stormwater Dischargers

DECISIONS INFORMED BY THE RMP

- **Which contaminants need to be reduced in municipal stormwater?** Reductions of legacy contaminants are currently a primary focus of stormwater management attention, but other contaminants, including contaminants of emerging concern, may also need to be reduced.
- **How much load reduction effort is needed?** The goal of TMDLs and other control plans is to reduce concentrations in the Bay to levels that do not significantly impact beneficial uses. This requires a solid understanding of the linkage between stormwater and Bay impairment.
- **Which tributaries should be priorities for actions to reduce loads?** Different segments of the Bay encompass variable watershed source areas and related loads, and vary greatly in their general characteristics, including in some cases their sensitivity to additional contaminant loads. The need for load reductions may therefore vary for tributaries discharging to different segments of the Bay.
- **Which sources or source areas in watersheds should be targeted for load reductions?** Identifying the sources and source areas in watersheds to target is a major challenge in reducing stormwater loads.
- **What is the effect of load reductions or other stormwater management and watershed modifications on Bay water quality?** Monitoring and modeling are essential to demonstrating that load reduction efforts achieve the desired improvement in beneficial use attainment. Other activities in the watershed (e.g., land use changes or changes in chemical use) may also affect contaminant loads in either beneficial or adverse ways.
- **Are actions needed for other pathways to reduce loads and impairment from contaminants found in municipal stormwater?** A holistic understanding of the relative importance of loads for all pathways is needed to optimize overall load reduction efforts.

REGULATIONS ADDRESSED

NPDES Permits

Municipal Regional Stormwater Permit

Mercury TMDL

PCBs TMDL

North Bay Selenium TMDL

Copper Site-Specific Objective Implementation Plan

CEC Action Plans

DTSC Safer Consumer Product Regulations

DPR state pesticide regulations

USEPA Federal Insecticide, Fungicide, and Rodenticide Act

RMP Impact Summary

Industrial Wastewater Dischargers

DECISIONS INFORMED BY THE RMP

- **Are treatment plant modifications or upgrades, or source reduction activities needed?**
 - **Which contaminants need to be reduced in industrial wastewater?** For example, the need for selenium reductions in refinery effluent was identified in the 1990s, and treatment upgrades implemented in the late 1990s achieved large reductions in selenium loads.
 - **At which treatment plants are the reductions needed?** Specific industrial discharges may contain higher levels of chemicals that may merit special attention. For example, sites where fire-fighting foams have been used may discharge higher levels of PFOS, a chemical of emerging concern present in older formulations. In addition, different parts of the Bay vary greatly in their general characteristics, including in some cases their sensitivity to additional contaminant loads. The need for load reductions may therefore vary in different segments of the Bay.
 - **How much of a reduction is needed?** The goal of TMDLs and other control plans is to reduce concentrations in the Bay to levels that do not significantly impact beneficial uses. This requires a solid understanding of impairment and contaminant cycling in the Bay.
 - **What is the effect of the reductions or modifications on Bay water quality?** Monitoring is essential in demonstrating that load reduction efforts achieve the desired improvement in beneficial use attainment. Monitoring is needed to ensure that treatment plant modifications (e.g., implementation of reverse osmosis for water reuse) have no adverse impacts on beneficial uses.
-
- **Are actions needed for other pathways to reduce loads and impairment from contaminants found in industrial wastewater?** A holistic understanding of the relative importance of loads for all pathways is needed to optimize overall load reduction efforts.

REGULATIONS ADDRESSED

NPDES Permits

Mercury TMDL

PCBs TMDL

North Bay Selenium TMDL

Copper SSO Implementation Plan

Mercury and PCBs Watershed Permit

CEC Action Plans

DTSC Safer Consumer Product Regulations

RMP Impact Summary

Dredgers

DECISIONS INFORMED BY THE RMP

- **Where can contaminated dredged material be disposed?** RMP sediment data are the basis for the Dredged Material Testing Thresholds for mercury, polycyclic aromatic hydrocarbons (PAHs), and PCBs. These thresholds determine when bioaccumulation testing is required for dredged material to be discharged at unconfined open water disposal sites in the Bay. RMP sediment data also serve as the basis for in-Bay dredged material disposal limits called for in the PCBs and mercury TMDLs.
- **Should dredged material be reused within the Bay and where?** Management of sediment as a resource in the Bay requires understanding of the volumes, types, locations, and environmental drivers of sediment input. The RMP performs extensive monitoring of suspended sediment concentrations along with monitoring of suspended sediment loads at select tributaries. The RMP also funds special studies to understand sediment transport within the Bay.
- **Should dredging practices be modified to prevent impacts to fish and benthic species?** The benthic communities of the Bay provide important foraging habitat for many fish species. The RMP performs studies to understand whether dredging practices have an impact on benthic species and habitats. The RMP also studies whether exposure to contaminants in dredged material poses a risk to fish.

REGULATIONS ADDRESSED

2011 Programmatic Essential Fish Habitat Agreement, Measure 1

2011 Programmatic Essential Fish Habitat Agreement, Measure 7

PCBs TMDL

Mercury TMDL

Long-Term Management Strategy





Program Area **UPDATES**

◀ In transit to the Golden Gate station on the
Status and Trends water cruise, 2023.

Program Area Update | STATUS & TRENDS

Background

The Status and Trends (S&T) monitoring program is the core of the RMP's long-term monitoring strategy. Since the beginning of the RMP in 1993, water, sediment, and bivalve tissue have been monitored regularly in the Bay. The Program has expanded to include the monitoring of sport fish, bird eggs, and prey fish which were added to the Program in 1997, 2007, and 2023, respectively.

In 2020, the RMP began a review of the S&T Program. Legacy contaminants have been the focus of the S&T Program since its inception, but are now of secondary priority behind contaminants of emerging concern (CECs). The number of CECs that are present in the Bay at concentrations that have a high probability of some impact on Bay aquatic life is increasing and CECs are becoming a major management focus in the region. Regulatory agencies are interested in having robust CEC data for the Bay so emerging issues can be detected before they cause substantial and potentially persistent effects on Bay water quality and beneficial uses.

Relation to Permit Requirements

NPDES Wastewater Discharge Permits

- Receiving water compliance monitoring for NPDES discharge permit holders
- Provides data for Reasonable Potential Analyses
- Provides data for evaluating site specific objectives for copper and cyanide

Essential Fisheries Habitat Consultation, PCBs TMDL, Mercury TMDL

- Provides data to calculate ambient dredged material testing guidelines

Uses of Program Area Data for Management Decisions

- Defining ambient conditions in the Bay
- Water Quality Assessment – 303(d) impairment listings or de-listings
- Determination of whether there is reasonable potential that a NPDES-permitted discharge may cause violation of a water quality standard
- Evaluation of water and sediment quality objectives
- Dredged material management
- Development and implementation of TMDLs for mercury, PCBs, and selenium
- Site-specific objectives and antidegradation policies for copper and cyanide
- Development and evaluation of a Nutrient Assessment Framework (i.e., development of water quality objectives)

Priority Questions

What are the concentrations and masses of priority contaminants in the Bay, its compartments, and its segments?

Are contaminants at levels of concern?

Are there particular regions of concern?

Have concentrations and masses increased or decreased?

What are the associated impacts of those contaminants?



Recent Findings

In 2021, the RMP started to implement the revised S&T design by adding CECs (bisphenols and organophosphate esters) to Bay water sampling. Samples for PFAS were also collected as part of a special study and then added to the S&T design in 2023. Monitoring of CECs in the Moderate Concern tier has been added to every sampling matrix (water, sediment, biota) as part of the S&T redesign.

A three-year pilot study to monitor CECs in Bay water during the wet season began in 2022. Samples were collected following three separate storm events from four targeted near-field stations (near where stormwater enters the Bay) and four stations along the spine of the Bay during the monthly USGS nutrients cruise. Samples will also be collected in the dry season to allow comparison between CEC concentrations in wet and dry seasons to understand how long CECs are present in the Bay, and if they are found at levels of concern.

Bird eggs were collected in 2022 after a one-year delay due to COVID-19. Sampling was limited to Double-crested Cormorants at three locations. Forster's Terns were dropped from the bird egg monitoring design as recommended in the S&T Review.

In the spring of 2023, muscle tissue plugs were collected from sturgeon in Suisun Bay for selenium analysis. This effort, originally scheduled for 2022, had also been delayed.

Monitoring of contaminants in harbor seals is being considered for addition to the S&T Program and a pilot two-year special study began in 2023.

◀ Deploying a conductivity, temperature, and depth (CTD) instrument package on the 2023 Status and Trends sediment cruise.



◀ A sediment total organic carbon (TOC) sample collected on the 2023 Status and Trends sediment cruise.

Workplan Highlights

The current sampling design, starting in 2022, is reflective of changes made to the Program through the S&T review process.

The sampling design includes:

- moored sensor network for continuous suspended sediment monitoring,
- nutrients - monthly,
- water, dry season - every two years,
- selenium in water, clams, and sturgeon - every two years,
- cormorant eggs - every three years,
- sediment - every five years,
- sport fish - every five years, and
- prey fish - every five years.

The RMP continues to collaborate with the US Geological Survey on the fortnightly South Bay and monthly Bay-wide cruises to assess nutrient and phytoplankton conditions in the Bay.

In 2023, the RMP is conducting biennial Bay water monitoring. Sediment monitoring (every 5 years) starting in 2023 will include the shallow margin areas of the Bay and near-field stations near watershed inputs to the Bay as part of the revised S&T monitoring design. Prey fish will also be monitored in 2023. In 2024, the RMP will conduct biennial selenium monitoring in water, clams, and sturgeon at two targeted North Bay stations and quinquennial sport fish tissue monitoring.

Collaborators

- San Francisco Bay Regional Water Quality Control Board
- US Environmental Protection Agency
- Applied Marine Sciences
- SGS AXYS
- Brooks Analytical Labs
- Eurofins Scientific
- Caltest Analytical Laboratory
- San Francisco Public Utilities Commission Water Quality Division
- US Geological Survey
- ALS Environmental
- Moss Landing Marine Laboratory
- Marine Pollution Studies Laboratory
- City of San Jose
- Gatecrasher Fishing Adventures
- Golden Bear Research Center
- Marine Applied Research and Exploration
- Enthalpy Analytical
- The Marine Mammal Center
- San Jose State University Research Foundation

Background

Contaminants of emerging concern (CECs) are generally un- or under-regulated and not routinely monitored, yet have the potential to enter the environment and harm people or aquatic life. Through its focus on CECs, the RMP aims to identify problem chemicals before they cause harm. The RMP's decades-long effort has made the Bay one of the most thoroughly studied estuaries in the world for CECs. Some of the RMP's top priorities for science and management include:

- PFAS — persistent, fluorine-rich stain and water-repelling “forever chemicals” that are widely used in industrial and consumer products
- Organophosphate Esters — flame retardants and ingredients in plastics

Other CECs of moderate concern for the Bay include urban pesticides like fipronil and imidacloprid, detergent compounds like alkylphenols and alkylphenol ethoxylates, and bisphenol A and related bisphenol plastic additives.

Relation to Permit Requirements

- Municipal wastewater dischargers may opt into the alternate monitoring permit requirements with fees that provide additional funds to support the RMP and its CEC monitoring.
- Municipal stormwater dischargers have jointly elected to fulfill local tributary CECs monitoring requirements through an additional annual contribution for RMP CECs monitoring.

Uses of Program Area Data for Management Decisions

- Regional Action Plans for CECs
- Early management intervention, including green chemistry and pollution prevention
- State and federal pesticide regulatory programs
- State Water Board CEC Program
- DTSC Safer Consumer Products Program

Priority Questions

Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay?

What are the sources, pathways, and loadings leading to the presence of individual CECs or groups of CECs in the Bay?

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?

Have levels of individual CECs or groups of CECs changed over time in the Bay or pathways? What are potential drivers contributing to change?

Are the concentrations of individual CECs or groups of CECs predicted to increase or decrease in the future?

What are the effects of management actions?



▲ Recording stormwater sampling information in Visitacion Valley in San Francisco, December 2022.

Recent Findings

The RMP is in the process of revising the CEC strategy that guides our monitoring and science. Discussions at workgroup meetings and within a CEC strategy subteam of stakeholders and science advisors have led to revisions to the guiding management questions as well as the tiered risk-based framework for CECs measured in the Bay. Draft chapters of the CEC strategy describe a four-element strategy consisting of 1) CEC monitoring and risk evaluation; 2) monitoring and modeling in contaminant pathways, in an effort to begin tracking Bay contaminants back to their sources; 3) use of novel approaches to identify additional CECs, including nontarget analysis and new approach methodologies (NAMs) for hazard assessment; and 4) review of the scientific literature and interactions with scientists around the world to learn from others and share expertise. We will complete the CEC strategy revision in 2024.

RMP monitoring revealed widespread occurrence of PFAS, also known as “forever chemicals,” at parts per trillion concentrations in the waters of the Bay. These compounds are persistent and toxic. The RMP analyzed Bay water in 2021 for 40 PFAS compounds to discern the occurrence, fate, and potential risks to ecological and human health. Eleven of 40 PFAS were detected in water collected from 22 sites. Concentrations were generally consistent with similar studies globally. While levels in Bay water may not pose risks to wildlife, they do suggest concern for people who eat fish from the Bay. The state of California has passed bans on PFAS in some products to reduce harmful exposures. For example, California will become the first state in the US to ban PFAS in apparel and textile products, starting January 2025. Other recent actions cover PFAS in cosmetics, children’s products, carpets and rugs, paper-based food packaging, and fire-fighting foams. Sustained, multi-matrix monitoring of this important class of CECs in the Bay is a high priority for the RMP to track the impacts of state PFAS restrictions.

The RMP conducts exploratory studies of CECs in municipal wastewater effluent and urban stormwater runoff. Recently completed wastewater studies include monitoring of sunscreen ingredients, as well as bisphenol A (BPA) and related plastic additives. Two of three sunscreens analyzed, oxybenzone and avobenzone, were detected in effluent from six major Bay Area facilities. Concentrations varied widely, and were generally higher than reported in another US study. Meanwhile, five of 17 bisphenols analyzed were detected in effluent from the same six wastewater treatment plants. A previous study at a single Bay Area facility found higher levels of BPA, suggesting a notable decrease in concentration over the prior 15 years.

Findings from the RMP’s multi-year stormwater CECs screening study are described in the Featured Project article (page 14).

Workplan Highlights

- **Integrated Monitoring and Modeling of CECs in Stormwater:** Early groundwork essential to developing a robust, practical, and cost-effective stormwater CECs monitoring approach is nearly complete. We will begin to pilot the new monitoring approach in the 2023/2024 wet season. A cornerstone of the evolving RMP approach is integration of modeling and monitoring designs to maximize the value of each stormwater sampling event.
- **Tire and Vehicle Contaminants in Bay Water:** A multi-year study is underway to quantify 6PPDQ and other contaminants derived from tires and vehicles in Bay water. Results to date indicate that after storm events, these contaminants reach detectable levels near stormwater discharge locations, as well as in the center of the Bay, even with dilution from mixing. Furthermore, 6PPDQ reaches concentrations that may be of concern for endemic salmonids including steelhead, both in creeks during storms and within near-shore Bay water just after storms. Findings will inform placement of these contaminants within the RMP tiered risk-based framework for prioritizing CECs.
- **PFAS and More in Marine Mammals:** The RMP launched a collaboration with The Marine Mammal Center and multiple analytical laboratories to investigate contaminants in tissues from two local species, harbor seals and harbor porpoises. This study includes nontarget analysis of PFAS and other halogenated compounds, providing a means to identify unanticipated contaminants that may merit follow-up monitoring. Results will inform decisions on whether to add marine mammals to long-term RMP Status and Trends monitoring.

Collaborators

- | | |
|---|--|
| • Bay Area Clean Water Agencies | • SGS AXYS |
| • Bay Area Municipal Stormwater Collaborative | • San Francisco Bay Regional Water Quality Control Board |
| • California Department of Toxic Substances Control | • San Diego State University |
| • California Department of Pesticide Regulation | • Southern Illinois University |
| • Clarkson University | • Stanford University |
| • Duke University | • University of Minnesota |
| • Eurofins Environment Testing | • University of Washington |
| • Jinan University | |

Program Area Update | SOURCES, PATHWAYS, AND LOADINGS

Background

The Sources, Pathways, and Loadings Strategy is being updated to address evolving information needs. Studies conducted over the past decade have focused primarily on locating, quantifying, and managing PCBs and mercury in the urban environment to support management actions. Going forward, an increasing emphasis will be placed on contaminants of emerging concern (CECs), along with tracking trends in PCB and mercury loading through a combination of methods development, monitoring, and conceptual and numerical modeling. Other pathways such as large river loading, wastewater, and atmospheric deposition may also be considered. The draft management questions provided here reflect these broadened needs.

Relation to Permit Requirements

Addresses monitoring requirements specified in the Municipal Regional Stormwater Permit, including:

- Source Identification - identifying or confirming which sources or watershed source areas provide the greatest opportunities for reduction in urban stormwater runoff;
- Contributions to Bay Impairment - identifying which watershed source areas contribute most to the impairment of Bay beneficial uses (due to source intensity and sensitivity of discharge location);
- Management Action Effectiveness - evaluating the effectiveness of impacts of existing management actions, including compliance with TMDLs and other requirements and providing support for planning future management actions;
- Loads and Status - providing information on loads, concentrations, and presence in local tributaries or urban stormwater discharges;
- Trends - evaluating trends in loading to the Bay and concentrations in urban stormwater discharges or local tributaries over time.

Uses of Program Area Data for Management Decisions

- Developing and refining loading estimates, including for CECs, for future policy or management plan updates (collaboration with Emerging Contaminants Workgroup)
- Informing provisions of the current and future versions of the Municipal Regional Stormwater Permit (MRP)
- Identifying sources, pathways, and high leverage areas to prioritize for management actions
- Tracking effectiveness of load reduction and changes in CECs presence and concentration in small tributaries
- Estimating present and future sediment loads to the Bay (collaboration with Sediment Workgroup)
- Supporting boundary concentration and loading conditions for Priority Margin Unit (PMU) and in-Bay modeling (collaboration with PCB Workgroup)



Priority Questions*

What are the sources, pathways, and loadings of pollutants and sediment to the Bay?

Which are the priority sources and pathways of pollutants that adversely impact or potentially adversely impact the Bay's environmental quality?

Are levels of individual pollutants or pollutant classes changing over time in the sources, pathways and loadings? What factors or management interventions have contributed to the change?

What are the effective management actions that can be implemented in the region to address pollutant pathways and sources, and where should they be implemented to have the greatest benefit?

**These are the draft revised Management Questions based on the May 23, 2023 Sources, Pathways and Loadings Workgroup Meeting. Note: "Pollutants" includes sediment, microplastics, and CECs.*

◀ Stormwater sampling in Belmont Creek, in Belmont

▶ Adjusting settings on an ISCO sampler for stormwater sampling in Belmont Creek, in Belmont.

Recent Findings

Development of a new dynamic, regional Watershed Dynamic Model (WDM) for Bay Area hydrology and sediment has been completed for Water Years (WYs) 1995-2020, with added funding from the California Coastal Conservancy. The spatial domain of this new model is the area that drains to the Bay from the nine adjacent counties. The Loading Simulation Program in C++ (LSPC) modeling framework was selected because of its capacity to simulate large complex regions with mixed land use types, a wide range of pollutants, upland erosion and sediment transport, and in-stream processes (e.g., bank erosion, settling, and resuspension). The completed model is performing well, reproducing the timing and peaks of runoff events as well as the annual and intra-annual variation of hydrological processes and sediment loads. Work is underway to model PCB and Hg loads and trends.

Winter storm sampling for PCBs and mercury by the RMP, utilizing a combination of manual sampling and unattended remote suspended sediment sampling, has been conducted in 94 watersheds. The watersheds with the highest PCB concentrations on exported particles are Pulgas Creek Pump Station in San Carlos, a ditch on Industrial Road in San Carlos, Line 12H at Coliseum Way in Oakland, and Santa Fe Channel in Richmond. Outfalls at Gilman

Street and the Santa Fe Channel sites also appear to have relatively high concentrations of mercury. Following historic consecutive dry seasons in water year (WY) 2020 and 2021, WY 2022 was approximately an average wet season, followed by a historic wet season in WY 2023. Two more watersheds were sampled in 2022 for characterization purposes. In 2023 intensive sampling in three watersheds was initiated to provide additional data to support calibration of the WDM for PCBs and mercury.

In WY 2023, a four-year hydrology and sediment loads study was completed for four watersheds selected to enhance the spatial heterogeneity of the calibration dataset for the WDM as well as contribute to a better understanding of the complex interactions between urban stormwater flows and sediment transport in the region. The study added information about watersheds at the higher end of sediment yields across the region. Climatically, the four-year period of study represented both dry, average, and wet years. In all four watersheds, the single largest day of discharge transported significantly greater sediment loads than the entire WYs 2020 and 2021 combined, highlighting the importance of monitoring during wet years in order to accurately estimate suspended sediment loads.

Workplan Highlights

- **Stormwater Sampling:** Over the past nine years, the RMP, in collaboration with county stormwater programs, has funded watershed reconnaissance sampling PCBs and mercury samples to identify high-leverage watersheds and subwatersheds within larger areas of older urban and industrial land use. In WY 2024 this effort will expand to include the use of a new remote sampler in tidal areas downstream from suspected PCB sources. Additionally, the RMP is continuing to conduct repeated stormwater sampling at selected sites with flow data (Arroyo Corte Madera del Presidio, Walnut Creek, and Guadalupe River) to support WDM calibration.
- **Regional Loads Estimates by RWSM:** The Regional Watershed Spreadsheet Model (RWSM) has so far provided support for reasonable assurance analysis and other planning efforts for PCBs and mercury, as well as estimates for regional-scale trash assessments, copper, and microplastics. It was also used to provide temporally and spatially down-scaled loading information for the boundary conditions of the one-box modeling in priority margin areas as part of RMP PCB studies. To maintain usefulness, models need maintenance to ensure they are able to optimally simulate the physical landscape in relation to our management questions. The RWSM is being updated to a more recent climatic period (1991-2020) that better fits the available pollutant concentration data, and the land use basis of the model is also being updated to reflect the new development and redevelopment that has occurred in the past 20 years.
- **Trends Strategy and WDM Development:** The evaluation of stormwater loading trends in relation to management efforts and beneficial use impacts is an important RMP focus. The medium-term plan is for the WDM to broadly support a wide range of contaminants, including CECs. The first trends simulations (for PCBs and mercury) are being developed. In 2024, this inaugural work will be built up by exploring model uncertainties, determining model sensitivities to parameter and data weaknesses, and providing PCB and mercury monitoring design recommendations. In parallel, the model will provide watershed loading estimates to be coupled with a new PCB fate model being developed for the Bay. A pilot study linking watershed modeling with Bay modeling is already underway.



Collaborators

- Bay Area Municipal Stormwater Collaborative
- San Francisco Bay Regional Water Quality Control Board
- US Geological Survey
- California Department of Pesticide Regulation
- SGS AXYS

Program Area Update | NUTRIENTS

Background

San Francisco Bay receives some of the highest nitrogen loads among estuaries worldwide, yet historically has not experienced the water quality problems typical of other nutrient-enriched estuaries. However, an unprecedented harmful algal bloom that occurred in August 2022 indicated that the resilience of the system may be declining. During the bloom, chlorophyll concentrations rose to levels in excess of 200 µg/L in some areas of the Bay, and measures of dissolved inorganic nitrogen dropped to near zero. There was widespread fish mortality across more than two thirds of the Bay, including severe impacts on white sturgeon and the federally-listed green sturgeon populations, and anoxic conditions throughout much of South Bay. The reoccurrence of a bloom in August 2023 with the same harmful algal species has further heightened concern that there has been a shift in the Bay's sensitivity to nutrients. This adds urgency to the work of the Nutrient Management Strategy and the need to identify long-term management options that would be effective at preventing or mitigating nutrient impacts. A wide range of monitoring, modeling, and special studies is planned to improve our understanding of Bay water quality and nutrient dynamics to inform management decisions.

Relation to Permit Requirements

The Bay-wide nutrient permit for municipal wastewater that went into effect in 2014 includes a provision to support science and monitoring to inform future permitting decisions. The second five-year Bay-wide nutrient permit started in 2019 and ends in 2024. Discussions have started for the renewal of the permit next year.

Uses of Program Area Data for Management Decisions

- Developing nutrient numeric endpoints and an assessment framework
- Evaluating the need for revised objectives for dissolved oxygen and other parameters
- Assessing water quality impairment status
- Implementing NPDES permits for wastewater and stormwater
- Informing decisions about management actions including potential load reductions.

Priority Questions

What conditions in different Bay habitats would indicate that beneficial uses are being protected versus experiencing nutrient-related impairment?

In which subembayments or habitats are beneficial uses being supported? Which subembayments or habitats are experiencing nutrient-related impairment?

To what extent is nutrient over-enrichment, versus other factors, responsible for current impairments?

What management actions would be required to mitigate those impairments and protect beneficial uses?

Under what future scenarios could nutrient-related impairments occur, and which of these scenarios warrant pre-emptive management actions?

What management actions would be required to protect beneficial uses under those scenarios?

What nutrient sources contribute to elevated nutrient concentrations in subembayments or habitats that are currently impaired, or would be impaired in the future, by nutrients?

When nutrients exit the Bay through the Golden Gate, where are they transported and how do they influence water quality in the Gulf of Farallones or other coastal areas?

What specific management actions, including load reductions, are needed to mitigate or prevent current or future impairment?

Recent Findings

The 2022 harmful algal bloom resulted in widespread fish mortality and anoxic conditions through much of South Bay. Ongoing research seeks to determine the conditions which enabled this historic event as well as the potential for *Heterosigma* blooms to reoccur.

High-frequency sensors are providing continuous data at 13 sites in Central Bay, South Bay, and Lower South Bay. These data show distinct conditions between shoal, channel, and slough habitats that vary on multiple timescales.

Lateral high-frequency mapping cruises of the South Bay shoals have provided a valuable view into this region, which is not adequately characterized by long-standing channel-based monitoring programs. Chlorophyll-a, oxygen, nutrients, and other parameters are being measured to investigate spatial and temporal patterns in production, with the data being used to validate models, inform monitoring design, and improve remote sensing algorithms.

Harmful algal bloom-forming phytoplankton species are commonly detected throughout the Bay, and multiple HAB toxins occur in water samples, anchovies, and mussels.

Current estimates suggest that the Bay is a significant source of nutrients to the coastal ocean. Ongoing modeling work aims to identify how this input affects coastal condition.

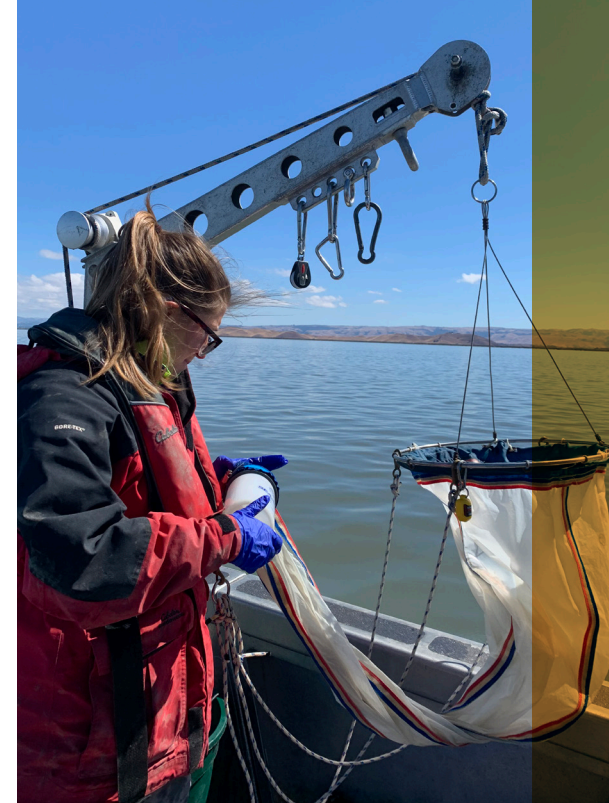
Progress continues on model simulations of nutrient transport, phytoplankton blooms, oxygen cycling, nutrient transformations, and other processes.

Workplan Highlights

- Analyzing data collected during the 2022 HAB event to determine what factors shaped the event
- Conducting high speed lateral mapping surveys of the South Bay shoal to characterize spatial patterns of nutrients and production
- Maintaining a network of high-frequency sensors in the South Bay and Lower South Bay
- Expanding the moored sensor network by establishing chlorophyll and dissolved oxygen sensors at Alcatraz in the Central Bay, and dissolved oxygen sensors at depth at the San Mateo and Dumbarton bridges
- Synthesizing biogeochemical data collected in the Lower South Bay to assess the link between salt pond production and sloughs
- Determining healthy DO-related habitat conditions in Lower South Bay sloughs and creeks and other margin habitats
- Forecasting conditions in the Bay under potential future scenarios
- Assessing the fate of nutrients that leave San Francisco Bay and the effects along the coast
- Developing trends analyses for key indicators of water quality
- Linking nutrient transformation rates measured in the field to the development of the biogeochemical model

Collaborators

- San Francisco Bay Regional Water Quality Control Board
- Bay Area Clean Water Agencies
- Baykeeper
- Deltares
- San Francisco State University
- Stanford University
- UC Berkeley
- UC Davis
- UC Santa Cruz
- US Environmental Protection Agency
- US Geological Survey – Sacramento
- US Geological Survey – Menlo Park
- US Geological Survey - Santa Cruz
- University of Maryland Center for Environmental Science
- South Bay Salt Pond Restoration Project
- Resource Management Associates
- Bend Genetics
- California Department of Water Resources



▲ Top: Deploying a zooplankton net aboard the R/V Peterson (photograph by Kristin Art). Bottom: NMS water quality buoy deployed on the shallow shoal in South San Francisco Bay (photograph by Ariella Chelsky).

Program Area Update | PCBs

Background

PCB contamination is a high priority for Bay water quality managers due to concerns for risks to humans and wildlife. A TMDL was approved in 2009, but concentrations in Bay sport fish have not declined since then, or even since RMP sport fish monitoring began in 1997.

In 2014, the RMP completed a synthesis report summarizing advances in understanding of PCBs in the Bay since the data synthesis for the PCBs TMDL. An updated conceptual model presented in that report indicated that local-scale actions within margin areas, or in upstream watersheds, will be needed to reduce exposure within these areas. The RMP multi-year workplan for PCBs is focusing on supporting a review of the PCBs TMDL in 2028 by evaluating the likelihood of improvements in high-priority margin areas in response to anticipated stormwater load reductions, and by establishing baselines for monitoring these improvements.

Site-specific conceptual models have been developed for three margin areas that are high priorities for water quality managers: the Emeryville Crescent, San Leandro Bay, and Steinberger Slough/Redwood Creek. Work is underway, with funding from the RMP and the USEPA Water Quality Improvement Fund, on development of a mechanistic fate model for PCBs and other contaminants in the Bay.

Relation to Permit Requirements

- Addresses critical information needs identified in the PCB TMDL related to municipal and industrial wastewater dischargers and stormwater management agencies
- Addresses a requirement in the Municipal Regional Stormwater Permit: Fate and transport study of PCBs - Urban runoff impact on San Francisco Bay margins

Uses of Program Area Data for Management Decisions

- PCBs TMDL – support for appropriate changes to the TMDL
- NPDES Municipal Regional Stormwater Permit and wastewater permit requirements
- Focusing management actions and/or locations for reducing PCB impairment (upland)
- Determining cleanup priorities (in-Bay)

Priority Questions

1. What are the rates of recovery of the Bay, its segments, and in-Bay contaminated sites from PCB contamination?

1a. What would be the impact of focused management of PMU watersheds?

1b. What would be the impact of management of in-Bay contaminated sites (e.g., removing and/or capping hot spots), both within the sites and at a regional scale?



Recent Findings

In 2019, shiner surfperch had a Bay-wide average concentration 18 times higher than the TMDL target. These concentrations have resulted in an advisory from the Office of Environmental Health Hazard Assessment (OEHHA) recommending no consumption for all surfperch in the Bay. Concentrations in shiner surfperch and white croaker show limited signs of decline.

Urban stormwater is the pathway carrying the greatest PCB loads to the Bay and with the greatest load reduction goals. Concentrations of PCBs and mercury on suspended sediment particles from a wide range of watersheds have been measured as an index of the degree of watershed contamination and potential for effective management action. The three sites with the highest estimated particle PCB concentrations as of 2019 were Pulgas Pump Station South (8,220 ng/g), Industrial Rd Ditch in San Carlos (6,139 ng/g), and Line 12H at Coliseum Way in Oakland (2,601 ng/g).

Assessments of three “priority margin units” (the Emeryville Crescent, San Leandro Bay [SLB], and the Steinberger Slough/Redwood Creek area [SS/RC]) established conceptual models as a foundation for monitoring response to load reductions and for planning management actions. A key finding was that PCB concentrations in sediment and the food webs in the Crescent and SLB could potentially decline fairly quickly (within 10 years) in response to load reductions from the watershed. In contrast, recovery in SS/RC appears likely to be limited ultimately limited by the relatively high PCB concentrations that prevail in the South Bay segment of the Bay at the regional scale.

In spite of the expected responsiveness of SLB, extensive field studies there have documented persistent sediment contamination that is likely due to continuing inputs from the watershed.

Workplan Highlights

- A major project that began in 2023 and will continue over the next several years will develop an in-Bay fate model for PCBs and other contaminants, leveraging and integrating with models for nutrients, sediment, and watershed contaminant loads. The initial focus is on modeling PCBs in San Leandro Bay. The project will include development of an enhanced food web model for PCBs.
- Continued monitoring of PCBs in shiner surfperch throughout the Bay in 2024 as part of RMP Status and Trends monitoring, including locations in priority margin units.
- To support in-Bay fate modeling, measurement of sediment deposition in the San Leandro Bay priority margin unit in 2024 using an array of tools, including sediment marker horizons, sediment pins, surface elevation tables, and sediment traps.

Collaborators

- Moss Landing Marine Laboratory
- SGS AXYS
- Stanford University
- Integral Consulting Inc.
- Simon Fraser University
- San Francisco Bay Water Board
- US Environmental Protection Agency



▲ Retrieval of a passive sampling device and a suspended sediment trap deployed in San Leandro Bay. Photograph by Yeo-Myoung Cho.

Program Area Update | MICROPLASTICS

Background

Microplastics, commonly defined as plastic particles smaller than 5 mm, come in a broad range of polymer types, shapes, and sizes. These properties affect the way microplastic particles move through the environment, and may modify their potential for toxicity. Information on the chemistry and morphology of particles can help to identify sources and options to mitigate the impact. While microplastics are abundant and ubiquitous, there is limited understanding of the ecological and human health risks related to the diversity of microplastics in the environment. As directed by state law, the California Ocean Protection Council has taken international leadership in developing a statewide microplastics strategy and supporting the development of a statewide plastics monitoring strategy.

In 2019, the San Francisco Estuary Institute completed a pioneering, three-year comprehensive regional study of microplastic pollution; this rich dataset provides the foundation to our understanding of microplastics in the Bay region and other urban regions in California and beyond. The project deliverables included a 400 page report on the scientific findings that has been widely cited, as well as several peer-reviewed science journal publications.

Microplastics have been monitored in Bay water, sediment, prey fish, bivalves, and the adjacent ocean. Microplastics were ubiquitous, and the concentrations in Bay water were higher than other major water bodies monitored to date with comparable methods. Microplastics ingested by prey fish and bivalves were mostly fibers, and indicate microplastics are entering the Bay food web. Average concentrations of microplastics measured in Bay stormwater were 100 times greater than average concentrations in Bay wastewater effluent, emphasizing the importance of outdoor sources and emission of microplastics in urban areas.

Relation to Permit Requirements

There are no current permit requirements for microplastics, although large plastic items (> 5 mm) that may fragment into microplastics are addressed in the Municipal Regional Permit for Stormwater and the statewide trash amendments and requirements.

Uses of Program Area Data for Management Decisions

- Statewide microplastics strategy and statewide drinking water monitoring
- Municipal, state, and federal plastic (including microplastics) pollution prevention strategies
- Local and state bans and other management actions on single-use plastics
- DTSC Safer Consumer Products Program decisions on regulation of chemicals in tires, food packaging, and building materials
- State and Federal bans on microbeads
- Statewide trash requirements

Priority Questions

What are the levels of microplastics in the Bay? What are the risks of adverse impacts?

What are the sources, pathways, processes, and relative loadings leading to levels of microplastics in the Bay?

Are microplastic levels changing over time? What are the potential drivers contributing to changes?

What are the anticipated effects of management actions?



A sieve used in sorting microplastic particles by size. ►
Photograph by Diana Lin.

Recent Findings

Motivated by findings on the importance of urban stormwater as a pathway for microparticles and microplastics in the environment, SFEI developed conceptual models of microplastic sources and pathways to urban stormwater. SFEI conducted a literature review and identified priorities for research and initial mitigation activities, providing support for Bay and statewide microplastic strategies and informing management efforts that will be effective in preventing microplastic pollution.

Tire wear particles may be the biggest source of microplastics to the Bay and to global receiving waters. This is supported by observations of tire wear particles in Bay Area stormwater samples, as well as literature estimates of 3-5 kg/yr of tire wear particles released per capita in the US. Using available science and market data to estimate tire wear generated in the Bay Area from cars and trucks driving on the road, an estimated 15-18 million kg of tire wear particles are generated in the region that has the potential to be transported to the Bay through urban stormwater runoff. Tire wear also disperses tire-related chemicals into the environment, and collaborations with the University of Washington, Tacoma identified various tire ingredients present in Bay stormwater runoff.

Fibers were the second most abundant type of particle observed in Bay stormwater samples, but the major source of the fibers is unclear. Based on ongoing literature review to understand the sources of pathways of microplastics, our hypothesis is that cigarette filters and tumble-air dryers are important sources of fibers that warrant further investigation.

The Southern California Coastal Water Research Project, State Water Board, SFEI, and various academic experts have collaboratively developed an online database and web tool that summarizes published literature on microplastic effects on human and wildlife health. The tool, ToMEx: Toxicity of Microplastics Explorer, is currently being updated to incorporate more recent studies with the potential to calculate new ecotoxicity thresholds. Findings in the form of peer-reviewed science journal articles are expected later this year.



▲ Collecting a stormwater microplastics sample in Visitacion Valley in San Francisco, December 2022.

Workplan Highlights

- **Microplastic Strategy Update.** Priority microplastic management questions have recently been reviewed and revised. A Microplastic Strategy Update will be developed that summarizes the most relevant scientific developments and priority data gaps most relevant to informing the revised management questions. In addition, coordination with other related microplastic efforts will be summarized, particularly with ongoing efforts to develop a state-wide plastics monitoring strategy.
- **Pilot Study for Field Collection Methods and Particle Distribution Analysis of Microplastics in Urban Stormwater to San Francisco Bay.** We will implement pilot studies to improve methods to sample and analyze microplastics in urban stormwater runoff. This will involve comparing stormwater sample collection using single-depth measurements versus depth-integrated samples, which will inform future stormwater sampling. We will also use advanced laboratory techniques that address important data gaps by characterizing tire wear and other fine particles.
- **Investigation of Clothes Dryers as a Source of Microplastics Pollution to Inform Solutions.** California Sea Grant and California Ocean Protection Council recently announced funding a SFEI-led (in collaboration with Desert Research Institute and 5 Gyres Institute) study to address the question of whether electronic clothes dryers are a major source of the microplastic fiber pollution to aquatic systems, as well as to investigate whether secondary dryer filters are an effective solution to capture microfibers. Findings for the Bay are relevant to other urban regions in North America where vented drying units are the predominant method of drying laundry.

Collaborators

- 5 Gyres Institute
- Bay Area Clean Water Agencies
- California Ocean Protection Council
- California State Water Resources Control Board
- Desert Research Institute
- Moore Institute for Plastic Pollution Research
- Pacific Northwest Consortium on Plastics
- Patagonia
- Southern California Coastal Water Research Project
- University of Toronto
- US Environmental Protection Agency
- University of Washington, Tacoma

Program Area Update | SEDIMENT

Background

Sediment is critical to the health of the San Francisco Bay ecosystem. Suspended sediment concentrations in Bay water have an important role in controlling algae blooms and subsequent anoxia by limiting light availability. Sediment delivered to the Bay from the surrounding watersheds and transported within the Bay carries priority pollutants such as PCBs and mercury. Sediment deposition on tidal marshes and mudflats allows these habitats to increase in elevation and keep pace with rising sea level. Sediment is dredged from Bay shipping channels, harbors, and ports; some of this dredged sediment is removed from the Bay completely, which helps remove contaminants from the system, and some is beneficially reused in wetland restoration projects.

The RMP has been monitoring sediment in the Bay since the Program began in 1993. In recent years, sea level rise has heightened interest in sediment supply to the Bay. The mass balance and transport pathways of Bay sediment are critical factors controlling the degree to which mudflats, marshes, and other shoreline habitats get the sediment supply needed to be resilient over the long-term. As the San Francisco Bay Restoration Authority decides how to allocate \$500 million over the next 20 years, it is critical to know the amount and quality of sediment available for restored tidal habitats.

In 2018, the RMP created a new Sediment Workgroup. The mission of the Workgroup is to provide technical oversight and stakeholder guidance on RMP studies addressing questions about sediment delivery, sediment transport, dredging, and beneficial reuse of sediment.

Priority Questions

What are acceptable levels of chemicals in sediment for placement in the Bay, baylands, or restoration projects?

Are there effects on fish, benthic species, and submerged habitats from dredging or placement of sediment?

What are the sources, sinks, pathways, and loadings of sediment and sediment-bound contaminants to and within the Bay and subembayments?

How much sediment is passively reaching tidal marshes and restoration projects and how could the amounts be increased by management actions?

What are the concentrations of suspended sediment in the Estuary and its segments?

Workplan Highlights

- **Richmond Bridge flux monitoring.** Understanding sediment flux between Bay subembayments is a critical data gap in understanding Bay-wide sediment transport dynamics. The RMP is funding the USGS to monitor suspended sediment flux at the Richmond Bridge (i.e., the boundary between San Pablo Bay and Central Bay) over the course of one water year. These findings will be useful in a range of applications, including constraining the contemporary Bay sediment budget and calibrating hydrodynamic models.
- **Sediment delivery to marshes.** Salt marshes around the Bay provide critical habitat and natural shoreline protection. The RMP is funding the USGS to investigate the factors controlling sediment delivery to and deposition tidal marshes in South Bay and North Bay. The effort includes measurement of suspended sediment flux in the shallows adjacent to a marsh, flux into the marsh through a tidal creek, deposition and accretion on the marsh, and the variation in deposition with elevation and vegetation density and type. Results will be useful for prioritizing marsh restoration sites, assessing restoration actions, and understanding mechanisms of sediment delivery to and sea level rise vulnerability of marshes.

Relation to Permit Requirements

Essential Fisheries Habitat Consultation, PCBs TMDL, Mercury TMDL

- Provides information for setting dredged material testing thresholds and in-Bay disposal limits
- Long-Term Management Strategy for Dredged Material in San Francisco Bay
- Provides information about sediment mass balance in the whole Bay, subembayments, and margin areas
- Informs dredged sediment thresholds for beneficial reuse projects

Uses of Program Area Data for Management Decisions

- NOAA 2011 Programmatic Essential Fish Habitat Agreement and 2015 LTMS Amended Programmatic Biological Opinion
- Long-Term Management Strategy for Dredged Material in SF Bay (LTMS) to comply with the Basin Plan
- Regional Restoration Plans
- PCB TMDL
- Mercury TMDL

Recent Findings

Bay Sediment Conceptual Model. This recently completed special study focused on producing detailed conceptual models of sediment dynamics for the Bay at a range of scales. The project incorporated recent monitoring and modeling results and working hypotheses of sediment dynamics at the Bay scale, subembayments scale, and marsh-mudflat scale. The final report identifies the data gaps that are considered most pressing to address in the near future, with an emphasis on fine-sediment supply for baylands habitat support. The results from this effort will be used to inform policy decisions and build frameworks for management, monitoring, and numerical modeling.

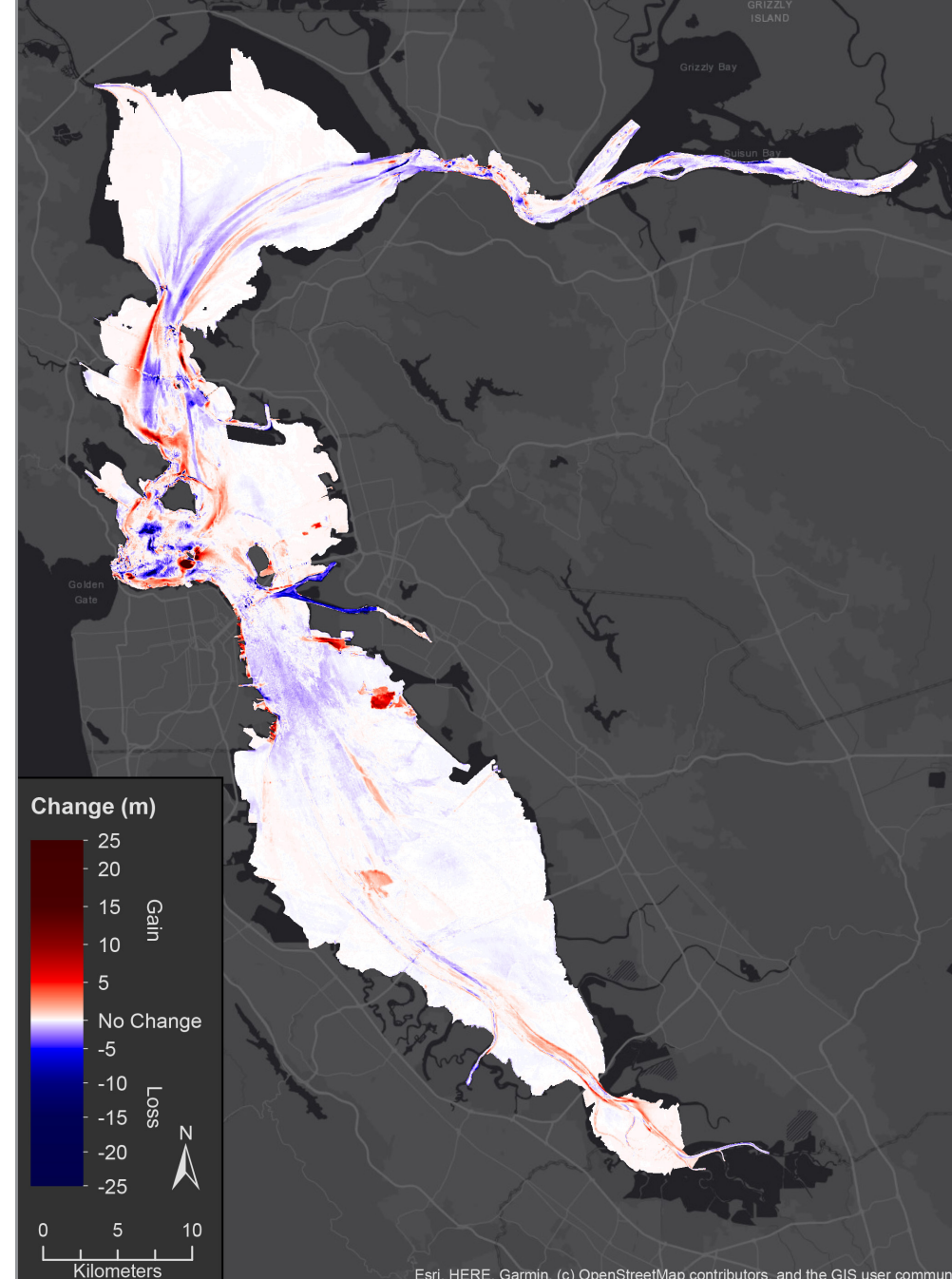
From 2019 to 2020, the RMP funded the USGS to compile Bay bathymetric data and calculate Bay-wide bathymetric change from the 1980s to the 2010s. This work showed that the Bay floor has been net erosional over the past several decades, losing approximately 34 million cubic meters of sediment. Suisun Bay showed the greatest amount of sediment loss (approximately 18 million cubic

meters) while Central Bay showed net accretion (approximately 5 million cubic meters). These findings can be used by ecosystem managers to inform a variety of sediment-related issues, including restoration of tidal marshes, exposure of legacy contaminated sediment, and strategies for the beneficial use of dredged sediment.

In July 2020, the USGS conducted research in South San Francisco Bay to assess the dominant controls on suspended sediment flocculation and associated particle settling velocity, which impacts the degree to which the Bay bed is eroding or accreting sediment. Data collection included gathering information on suspended sediment flocculation, wave energy, and flow dynamics. The results show that the relationship between suspended sediment settling velocity and local flow turbulence can vary considerably based on the method used to determine settling velocity. The results from this project will be useful for calibrating numerical models that simulate Bay sediment transport processes.

Collaborators

- Anchor QEA
- Bay Conservation and Development Commission
- Bay Planning Coalition
- Integral Consulting Inc.
- San Francisco Bay Regional Water Quality Control Board
- South Bay Salt Ponds Restoration Project
- US Army Corps of Engineers
- US Environmental Protection Agency
- US Geological Survey - Pacific Coastal and Marine Science Center
- US Geological Survey - Western Ecological Research Center



▲ Map showing bathymetric change in San Francisco Bay from the 1980s to the 2010s. From: Fregoso, T.A., Foxgrover, A.C., and Jaffe, B.E., 2023, Sediment deposition, erosion, and bathymetric change in San Francisco Bay, California, 1971–1990 and 1999–2020: U.S. Geological Survey Open-File Report 2023–1031, 19 p., <https://doi.org/10.3133/ofr20231031>.

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Unloading samples from the TomCat at the Benicia Marina at the end of the 2023 Status and Trends water cruise.



RMP

REGIONAL MONITORING
PROGRAM FOR WATER QUALITY
IN SAN FRANCISCO BAY

sfei.org/rmp

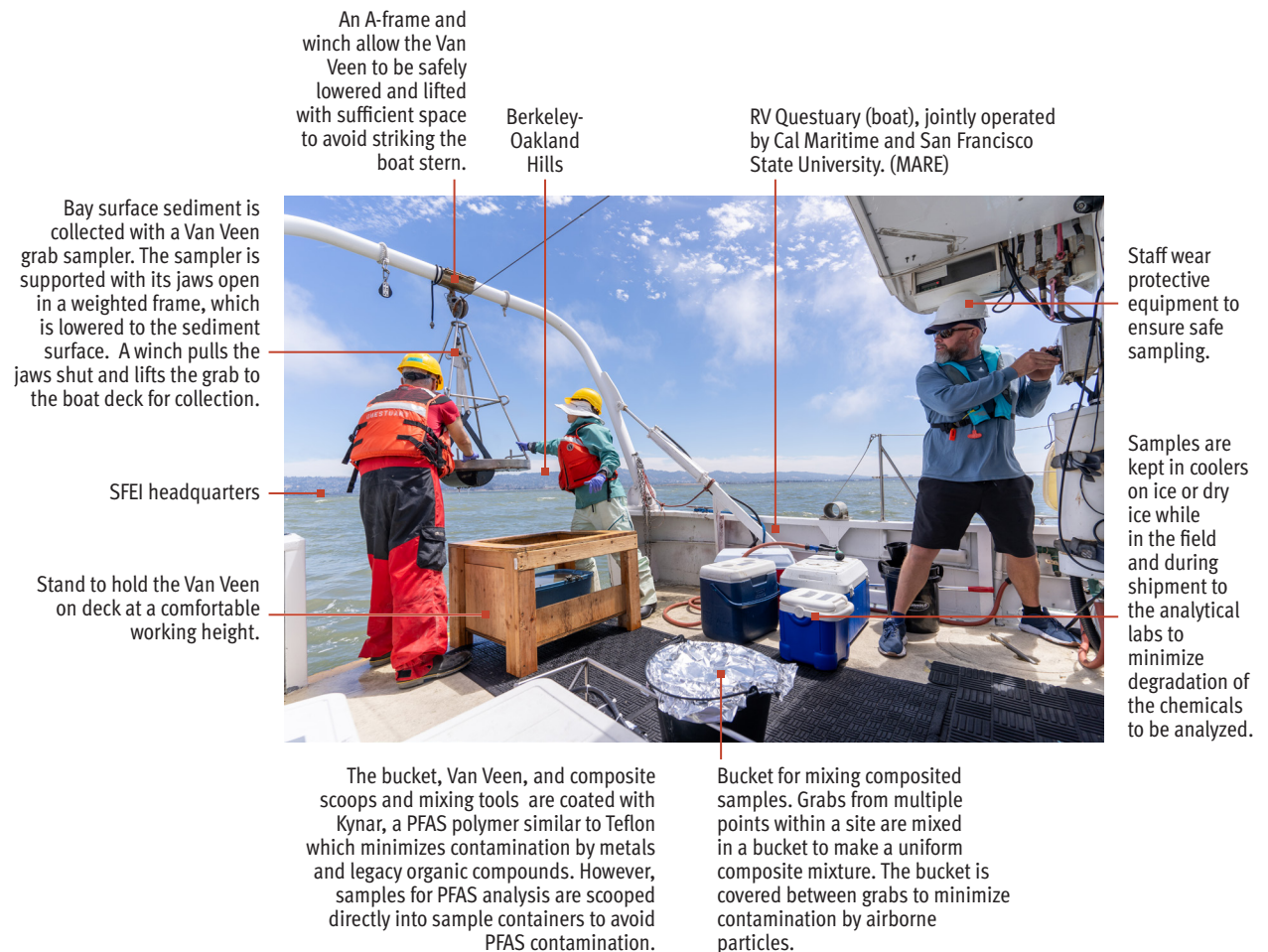
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THE STORY BEHIND THE COVER

Sediment Sampling in Central Bay

The new design of the RMP Status and Trends (S&T) element calls for monitoring sediment once every five years. Implementation of the new design began in 2023. This round of sediment sampling included two additions to the Bay-wide sampling of deep Bay sediment that has been conducted since the RMP began in 1993. First, S&T sediment sampling now includes sampling of shallow mudflat areas on a regular basis. Second, “near-field” sampling of sediment in a few selected areas near the points where stormwater and wastewater enter the Bay are included to measure the strongest possible in-Bay signal of contamination. All of this monitoring now has a focus on emerging contaminants that accumulate in sediment: specifically PFAS and bisphenols.

San Francisco Bay, January 2019. Credit: Copernicus Sentinel data, processed by ESA, CC BY-SA 3.0 IGO



WATER SAMPLING IN CENTRAL BAY	
DATE	07/24/2023
LOCATION	Central Bay near Berkeley
SAMPLING	Bay surface sediment samples collected to monitor contaminants and other sediment characteristics
WEATHER	A sunny day with a high of 70°F in Berkeley
DURATION	Noon to 1:00 PM
FIELD CREW	Don Yee, Jennifer Dougherty, Paul Salop (AMS), Ellen Goldenberg (AMS)
VESSEL AND CREW	Nic Shields and Stephen Kielar (Golden Bear Research at Cal State Maritime Academy)

SAMPLING EQUIPMENT
Van Veen grab sampler and weighted frame
Overhead A-frame and winch
Coolers for holding and shipping sample jars
Sample scoops
Sample jars and vials
Composite bucket and mixing tools
Nitrile gloves
Lifejackets, hard hats, and boots
Water quality datalogger

COVER PHOTOGRAPH BY SHIRA BEZALEL