REGIONAL MONITORING PROGRAM

UPDATE 2020

THE STORY BEHIND THE COVER

Stormwater Sampling at the Bay's Edge

Rain falling on land surfaces in the San Francisco Bay watershed produces stormwater runoff that carries pollutants, mostly untreated, into storm drains, creeks, and ultimately, the Bay. Urban stormwater is the largest pathway for many pollutants of concern in the Bay, including PCBs, dioxins, PAHs, many trace metals and pesticides, and microplastics. Meeting the load reduction goals for stormwater is one of the biggest hurdles to improving Bay water quality. Since 2015, RMP stormwater monitoring has focused on screening runoff from a large number of watersheds for PCBs and mercury, identifying those with relatively high concentrations that signal a greater potential for cost-effective management.

San Francisco Bay. Landsat imagery, April 2013, courtesy of NASA

Measured volumes collected at timed intervals are combined for a composite sample representative of conditions over the course of a storm

Central San Francisco Bay

Rigorous sampling protocols ensure consistency and lack of extraneous contamination

Chilly weather and gray skies after a storm that generated stormwater runoff

Trash at water's edge

Stormwater spilling into the Bay

Coolers and bottles pre-labeled with the sampling location and samples to be collected

OUTFALL AT GILMAN STREET STORMWATER SAMPLING

DATE	01/16/2020
LOCATION	Outfall at Gilman Street, Berkeley, CA
SAMPLING	Urban stormwater for analysis of PCBs, mercury, a variety of CECs, and suspended solids
WEATHER	A rainstorm brought over 1 inch of rain Temperature range: 54°– 61° F
DURATION	6:00 AM to noon
FIELD CREW	Matt Benjamin, Diana Lin, Don Yee

SAMPLING EQUIPMENT

Coolers for storing samples
Pump and battery
Sample bottles
Nitrile and polyvinyl gloves
Wet weather gear and heavy boots
Graduated cylinder
Record log
Sampling pole and tubing

COVER PHOTOGRAPH BY DON YEE

RMP UPDATE 2020

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

NOTE TO READERS: The RMP produces *The Pulse of the Bay* in odd years, and the *RMP Update* in even years. In contrast to *The Pulse*, which 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.

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

COMMENTS OR QUESTIONS regarding the RMP Update can be addressed to Dr. Jay Davis, RMP Lead Scientist, (510) 746-7368, jay@sfei.org.

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To download this report please visit www.sfei.org/rmp/update

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

CONTENTS


CAPE FEAR

PROGRAM IMPACT

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 $3.8 million annual budget for the RMP is used judiciously so that these decisions on Bay water quality are informed by sound science.

◀ San Francisco skyline and Bay Bridge. Photograph by Shira Bezalel.

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 plan for copper
- 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

◀ Fishing at Middle Harbor Shoreline Park in Oakland. Photograph by Shira Bezalel.

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 HIGHLIGHTS

The RMP TOP 10
Recent Activities and Accomplishments

1 CECs
Updated CEC Strategy — Increased Concern for Several Contaminants

An update of the RMP's Contaminant of Emerging Concern (CEC) Strategy in 2020 provided the rationale for the elevation of five CECs into the Moderate Concern category of the Program's tiered risk-based framework. Contaminants in this category have a high probability of at least a low level impact on Bay aquatic life.

PFAS are fluorine-rich and persistent chemicals, and some have bioaccumulated in Bay harbor seals and cormorant eggs at potentially concerning concentrations. Imidacloprid is a pesticide that has been detected in Bay water at a level exceeding a protective threshold, and is in widespread and increasing use. Microplastics are a highly diverse class of pollutants where protective thresholds have not been established, but technical experts and RMP stakeholders are in consensus that their persistence, increasing abundance, and potential risks to aquatic life merit the Moderate Concern classification. Bisphenols and organophosphate esters are endocrine-disrupting classes of synthetic compounds that are manufactured in high volumes, water soluble, and not effectively removed via traditional wastewater treatment processes. The 2020 Strategy Update also outlines a strategy for evaluating the potential toxicological risks of data-poor contaminants. The Update concludes with the current multi-year plan for RMP special studies on CECs, which includes a full revision of the CEC Strategy in 2021.

MORE INFORMATION

RMP TECHNICAL REPORT AND LINKS: Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations, 2020 Update

https://www.sfei.org/documents/contaminants-emerging-concern-san-francisco-bay-strategy-future-investigations-2020-update

2 CECs
Journal Article on Flame Retardants in the Bay

Flame retardant chemical additives are incorporated into consumer goods to meet flammability standards, and many have been detected in the Bay. The RMP recently funded a uniquely wide-ranging characterization of flame retardants, including polybrominated diphenyl ethers (PBDEs) and 52 additional brominated, chlorinated, or phosphate chemicals, in water, sediment, bivalves, and harbor seal blubber.

Among brominated flame retardants, PBDEs remained the dominant contaminants in sediment and biota, though declines have been observed over the last decade following their phase-out. Hexabromocyclododecane (HBCD) and other brominated flame retardants were detected at lower levels than PBDEs in sediment and tissue matrices. Dechlorane Plus (DP) and related chlorinated compounds were also detected at lower levels or not at all across all matrices. In contrast, organophosphate ester flame retardants were widely detected in Bay water samples. Concentrations in Bay water were often higher than in other estuarine and marine environments. Organophosphate esters were also widely detected in sediment, and several were present in bivalves. Only four phosphate flame retardants were detected in harbor seal blubber. Periodic multi-matrix screening is recommended to track contaminant trends impacted by changes to flammability standards and manufacturing practices, with a particular focus on contaminants like TDCPP (also known as "chlorinated tris") that were found at levels comparable to thresholds for aquatic toxicity.

MORE INFORMATION

JOURNAL ARTICLE AND LINKS: Characterization of brominated, chlorinated, and phosphate flame retardants in San Francisco Bay, an urban estuary (2019)

https://www.sfei.org/documents/characterization-brominated-chlorinated-and-phosphate-flame-retardants-san-francisco-bay

https://www.sciencedirect.com/science/article/abs/pii/S004896971833969X?dgcid=coauthor

3 CECs

Journal Article on the Long-term Fate of PFAS in the Bay

SFEI senior scientist Dr. Rebecca Sutton co-authored a study published in the journal Chemosphere that modeled long-term trends of perfluorooctane-sulfonate (PFOS) and perfluoro-octanoic acid (PFOA) over time in the Bay. This study was a collaboration with Francisco Sanchez-Soberón of the Universitat Rovira iI Virgili in Tarragona, Spain. PFOS and PFOA are the most widely studied per- and polyfluoroalkyl substances (PFAS), and are in the Moderate Concern category of the RMP tiered framework for CECs. PFAS have been widely used as water and stain repellents, such as in nonstick coatings. Their presence in the environment is concerning because they are harmful to humans (causing liver damage, endocrine disruption, fertility decrease, and cancer) and to wildlife. In particular, exposure to PFAS through consumption of Bay fish is a concern.

A model was used to predict future PFAS concentrations, using sediment and water concentrations measured by the RMP in 2009 in the North, Central, and South Bay regions. Concentrations of PFOA and PFOS exhibited slowly decreasing trends in response to anticipated load reductions, but with different timescales depending on region, compound, and compartment assessed. Nearly steady-state PFOA concentrations were reached after 50 years, while PFOS needed close to 500 years to reach steady-state in sediment and fish. Concentrations in fish stabilized between 0.007 and 0.10 ng/g wet weight, depending on compound and region. South Bay had the greatest final concentrations of pollutants.

MORE INFORMATION

JOURNAL ARTICLE AND LINKS: Multi-box mass balance model of PFOA and PFOS in different regions of San Francisco Bay (2020)

https://www.sfei.org/documents/multi-box-mass-balance-model-pfoa-and-pfos-different-regions-san-francisco-bay

https://pubmed.ncbi.nlm.nih.gov/32197174/

4 Microplastics

Results and Policy Recommendations from Pioneering Million Dollar Study

A major Bay microplastics monitoring and modeling effort, funded primarily by the Gordon and Betty Moore Foundation with additional support from the RMP and others, was completed in 2019. To collect critical baseline data and inform solutions, the San Francisco Estuary Institute and the 5 Gyres Institute conducted the first comprehensive regional study of microplastic pollution in a major estuary.

The project included multiple components to characterize microplastics in the Bay and adjacent National Marine Sanctuaries: developing and standardizing sample collection and analysis methodology; establishing baselines in Bay surface water, sediment, bivalves, and fish, and in ocean waters; characterizing pathways by which microplastics enter the Bay, including urban stormwater and treated wastewater effluent; evaluating the transport of microplastics throughout the Bay and to the adjacent ocean through computer simulations; communicating findings to regional stakeholders and the general public through meetings and educational materials; and facilitating evaluation of policy options for the Bay, with recommendations on source reduction. One key finding was that the estimated microplastic load from stormwater was over 300 times greater than the estimated load from municipal wastewater treatment plants discharging into the Bay. Nearly half of the particles in stormwater were black fragments that had a distinctive rubbery texture. While the identification of these particles was not definitive, one potential source of these particles is vehicle tire wear.

MORE INFORMATION:

REPORTS, MEDIA COVERAGE, PROCEEDINGS FROM A SYMPOSIUM AND WEBINAR, AND MORE are available from the SFEI microplastics web page

MAIN TECHNICAL REPORT AND LINKS: Understanding Microplastic Levels, Pathways, and Transport in the San Francisco Bay Region (2019)

https://www.sfei.org/documents/understanding-microplastics


Los Angeles Times

HOUSE ISSUES THREATS, TRUMP RAGES

L.A. vows to void 2 million court citations and warrants

Cars pollute the sea too, with tire rubber

A test-optional route into UC?


The Mercury News

Plastic tide: 7 trillion bits wash into bay every year

Pompeo, House chairmen clash

5 Sediment

Workshop on Sediment Screening Guidelines for the Beneficial Reuse of Dredged Material

As sea level rise threatens wetland habitats around the Bay, beneficial reuse of dredged sediment is becoming increasingly important. While the overall goal is to ensure that as much sediment as possible is available for beneficial reuse, the process also needs to be protective of the habitats receiving the sediment, as well as the aquatic species that live in those habitats, some of which are consumed by humans. Dredged sediment is currently being used in restoration projects around the Bay, but additional sediment is needed to meet the demand. The guidelines for determining if sediment is appropriate for beneficial reuse were developed 20 years ago. As part of assessing the role of dredged sediment in Bay restoration and adaptation strategies, the RMP and stakeholders recognized the need to revisit the beneficial reuse guidelines for dredged sediment.

In September 2019, the RMP convened a workshop that included four technical experts to review the beneficial reuse guidelines. The experts highlighted areas where the current process for screening sediment for beneficial reuse could be improved. Some of the recommendations could be easily implemented (e.g., update values to current ambient levels), while other changes will take more time and consideration of ecological, economic, social, and political goals. Carefully considering how risk and uncertainty are accounted for and evaluated will be important components of an updated process.

MORE INFORMATION

RMP TECHNICAL REPORT: Expert Review of the Sediment Screening Guidelines for the Beneficial Reuse of Dredged Material in San Francisco Bay (2020)

https://www.sfei.org/documents/expert-review-sediment-screening-guidelines-beneficial-reuse-dredged-material-san

6 Sediment

Tracking Sediment Movement and Supply in the Bay

Accurate suspended sediment flux measurements in coastal settings such as San Francisco Bay are of increasing interest given the importance of sediment supply for tidal marsh restoration and coastal resiliency to sea level rise, as well as the influence of suspended sediment on Bay water quality. However, current approaches to measure the movement (or "flux") of suspended sediment between segments of tidal systems (e.g., between South Bay and Lower South Bay) often exhibit very large uncertainty in both the magnitude and, at times, net direction of flux. Accurately measuring suspended sediment flux in tidal coastal systems is especially difficult because the total flux is often a small difference between two very large numbers.

An ongoing study at the Dumbarton Bridge refined flux estimates between South Bay and Lower South Bay by accounting for changes in the vertical suspended sediment profile due to flocculation of particles. This updated approach led to large estimated changes not only in the magnitude but also the direction of cumulative sediment flux. For example, based on data from a mid-depth sensor, sediment flux estimates changed from 388 kilotonnes moving out of Lower South Bay to to 1,869 kilotonnes moving into Lower South Bay for 2013–2016. This refined method will next be applied to flux estimates at the Benicia Bridge and is expected to improve estimates for sediment moving from the Delta into the North Bay.

MORE INFORMATION

JOURNAL ARTICLE: Suspended Sediment Flux in the San Francisco Estuary: Part I—Changes in the Vertical Distribution of Suspended Sediment and Bias in Estuarine Sediment Flux Measurements (2020)

https://www.sfei.org/documents/suspended-sediment-flux-san-francisco-estuary-part-i%E2%80%94changes-vertical-distribution

https://link.springer.com/article/10.1007/s12237-020-00734-z

7 Nutrients

Dissolved Oxygen in South San Francisco Bay

Dissolved oxygen (DO) is a key water quality parameter that is used as an indicator of nutrient enrichment in estuaries around the world. In 2017-2018, SFEI conducted a study to assess where and when regions of Lower South Bay (LSB) provide adequate DO to support resident fish species. The study involved convening a team of experts to advise on methods, analyzing high frequency DO measurements from seven RMP-funded mooring stations in LSB, and partnering with researchers from UC Davis to interpret several years of monthly fish abundance data in LSB relative to DO and other factors.

Analysis of continuous DO measurements indicated that low concentrations occur frequently in LSB and likely originate in sloughs and other perimeter habitats. In particular, sloughs that have elevated organic matter from managed pond discharges, other sources, or natural conditions have higher oxygen demand. As a result, water in the sloughs is depleted of its DO as it is transported through the estuary by diurnal tides. Fishes in the LSB exhibit diverse responses to variation in DO, likely driven by a variety of potential mechanisms (e.g., physiology, population dynamics, and ecological interactions). Mechanistic models of DO concentrations throughout LSB and additional analyses and targeted studies of fish responses to environmental conditions are needed to advance our understanding of the drivers of abundance and the relative importance of hypoxia to LSB fish communities.

MORE INFORMATION

TECHNICAL REPORT: Dissolved Oxygen in South San Francisco Bay - Variability, Important Processes, and Implications for Understanding Fish Habitat (2018)

https://www.sfei.org/documents/dissolved-oxygen-south-san-francisco-bay-variability-important-processes-and-implications

A mooring station probe with sensors for conductivity (salinity), temperature, pressure (depth), turbidity, dissolved oxygen, chlorophyll, and dissolved organic matter. ▶ Photograph by Derek Roberts.

8 Sources, Pathways, and Loading

Watershed Reconnaissance for PCBs and Mercury

In 2015, the Regional Water Board issued the second iteration of the Municipal Regional Permit for Stormwater. "MRP 2.0" placed an increased focus on identifying watersheds, source areas, and source properties that are potentially the most polluted and are therefore most likely to be cost-effective areas for addressing load-reduction requirements. To support this increased focus, a stormwater reconnaissance monitoring field protocol was developed and implemented in water years (WYs) 2015 through 2019.

Based on this dataset a number of sites with elevated PCB and mercury concentrations in stormwater and on sediment particles carried by stormwater have been identified, including 25 sites (28%) with estimated particle concentrations of PCBs greater than 200 ng/g and 31 sites (35%) with estimated particle concentrations of mercury greater than 0.5 µg/g. Most evidence suggests that, as a general category, old industrial land use exhibits the greatest loads and yields of PCBs relative to other land uses in the region. This study is continuing into WY 2020 with the goal of identifying areas for follow-up investigation and possible management action. The focus will continue to be on finding new areas of concern, although follow-up sampling will occur at some sites to verify previous sampling results.

MORE INFORMATION

RMP TECHNICAL REPORT: Pollutants of Concern Reconnaissance Monitoring Progress Report, Water Years 2015 - 2019 (2020)

https://www.sfei.org/documents/pollutants-concern-reconnaissance-monitoring-progress-report-water-years-2015-2019

9 PCBs

Assessing Recovery from PCB Contamination in Steinberger Slough/ Redwood Creek

The goal of RMP PCB special studies over the next few years is to inform the review and possible revision of the PCBs TMDL and the corresponding requirements in the reissued Municipal Regional Permit for Stormwater. Conceptual models are being developed for selected margin areas downstream of watersheds that are high priorities for management. The conceptual models will provide a foundation for establishing effective and efficient monitoring plans to track responses to load reductions, and will also help guide management actions.

A conceptual model for PCBs in the Steinberger Slough/Redwood Creek marsh complex was completed in 2020. A simple mass budget model suggests that concentrations of PCBs in water and sediment would respond fairly quickly to reductions in loads, but not as quickly as Emeryville Crescent or San Leandro Bay. The magnitude of the reduction would ultimately be limited by the relatively high PCB concentrations that prevail in the South Bay segment at the regional scale. Significant cleanup actions from major source areas in the watershed are in progress or under consideration (in the Pulgas Pump Station South watershed and the Delta Star Inc. and Tiegel Manufacturing properties in a small watershed draining to Steinberger Slough) and could result in large load reductions.

MORE INFORMATION

RMP TECHNICAL REPORT: Conceptual Model to Support PCB Management and Monitoring in the Steinberger Slough/Redwood Creek Priority Margin Unit (2020)

https://www.sfei.org/documents/conceptual-model-support-pcb-management-and-monitoring-steinberger-sloughredwood-creek

10 Status and Trends

Contaminants in South Bay Margins Sediment

The Bay margins (i.e., mudflats and adjacent shallow areas of the Bay) are important habitats where there is high potential for aquatic life to be exposed to contaminants. However, until recently, these areas had not been routinely sampled by the RMP due to logistical considerations. In 2015, the RMP began an additional set of surveys of sediment in the margins of the Bay, beginning with Central Bay. In 2017, South Bay margins were sampled.

The average mercury concentration in South Bay margin sediment was actually significantly lower than in the open waters of South Bay, which is counterintuitive because the margins are generally closer to pollution sources. When the concentrations were adjusted for the amount of fine-grained sediment in the samples, however, there was no difference between margins and open Bay. Concentrations of mercury and other particle-associated contaminants are higher on fine-grained sediment particles due to their higher ratio of surface area to volume. The average PCB concentration in South Bay margin sediment (11.5 ppb) was slightly, but statistically significantly, higher than in the open waters of South Bay (10.3 ppb). The difference was larger when the concentrations were adjusted for the amount of fine-grained sediment in the samples (17.6 ppb versus 14.3 ppb). A survey of the North Bay margins is being conducted in 2020.

MORE INFORMATION

RMP TECHNICAL REPORT: Characterization of Sediment Contamination in South Bay Margin Areas (2019)

https://www.sfei.org/documents/characterization-sediment-contamination-south-bay-margin-areas

Sampling PCBs in Steinberger Slough. Photograph by Don Yee. ▶

COMING ATTRACTIONS

1 CECs
CECs in Stormwater

A major multi-year study to measure CECs in urban stormwater began in 2019 and is continuing through 2021. A long list of CECs will be analyzed, including PFAS, ethoxylated surfactants, phosphate flame retardants, and others. Results will be reported in 2022.

2 Microplastics
Conceptual Model of Microplastics in Urban Stormwater

Recent work in the Bay indicated that urban stormwater is an important pathway for microplastics. This two-year study is summarizing available information to identify true sources and environmental release mechanisms, as well as possible factors influencing microplastic loads. A report on the study will be prepared in 2021.

3 Sediment
Changes in Bay Bathymetry

Assessing the Bay's changing bathymetry, or seafloor topography, is essential to understanding sediment dynamics. The RMP is funding the US Geological Survey to compile bathymetric data throughout the Bay to calculate bathymetric change over time, as well as highlight and prioritize data gaps. A final report on the two-year study will be completed in 2021.

Status and Trends 4
Updated Status and Trends Design

The first major re-design of RMP Status and Trends monitoring since 2002 is underway, with input from external advisors and stakeholders. A major goal is to optimize the design for monitoring CECs. Completion of the design process is anticipated in early 2022.

5 Status and Trends
North Bay Margins Sediment

In 2020, the RMP is finishing the third and final sampling area for margin sediment - North Bay - with stations located in San Pablo Bay, Carquinez Strait, and Suisun Bay. A report summarizing the results of this study, and comparing them to the results from the margin areas of Central and South Bay, will be completed in 2022.

6 Status and Trends
Results from 2019 Sport Fish Monitoring

The RMP monitors Bay sport fish on a five-year cycle, with the latest round occurring in 2019. A variety of parameters are being measured, including mercury, PCBs, selenium, dioxins, PFAS, and PBDEs. A report on the results will be available in 2021.

7 PCBs
Shiner Surfperch PCB Survey

RMP PCB studies in the last few years have focused on characterizing four priority margin areas (Emeryville Crescent, San Leandro Bay, Steinberger Slough, and Richmond Harbor). PCBs are being analyzed in shiner surfperch from these areas in coordination with the 2019 Status and Trends sport fish monitoring, as a baseline for tracking long-term trends.

8 Small Tributaries
Watershed Load Modeling

The RMP developed a multi-year plan in 2018 to assess trends in regional contaminant loads over decadal scales through a combination of modeling and monitoring. A Modeling Implementation Plan was completed in 2019. In 2020, the first stage of modeling, developing a hydrologic model for the Bay, was initiated. A sediment model will be developed in 2021.

9 Selenium
North Bay Monitoring

The RMP has developed a plan to track selenium trends in the North Bay through the monitoring of sturgeon, clams, and water, with a special emphasis on early detection of change. Annual monitoring of clams and water began in 2019; sturgeon samples will be added in 2020. Results from clam and water monitoring in 2019 and 2020 will be reported in 2021.

10 Pulse of the Bay 2021

The RMP publishes The Pulse of the Bay every other year, with the next edition coming in 2021.

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.

The **Technical Review Committee** (TRC) provides oversight of the technical content and quality of the RMP, making recommendations to the Steering Committee.

*currently inactive

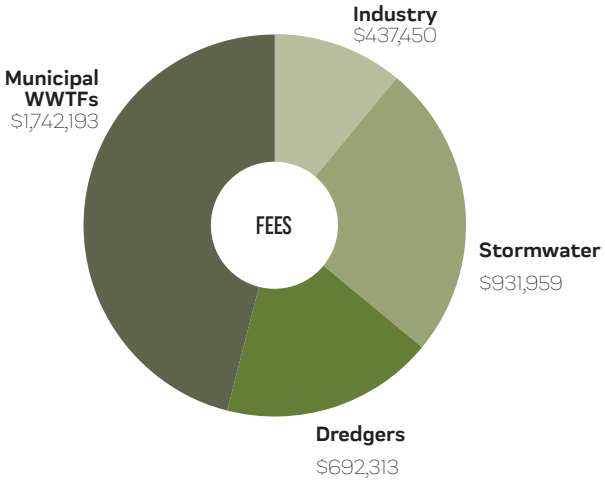
Workgroups report to the TRC and address the main technical subject areas covered by the RMP. The Nutrient Technical Workgroup was established as part of the committee structure of a separate effort — the Nutrient Management Strategy. This workgroup makes recommendations to the Nutrient Steering Committee on the use of RMP and other funds that support nutrient studies. The workgroups consist of regional scientists and regulators and invited scientists recognized as authorities in their 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

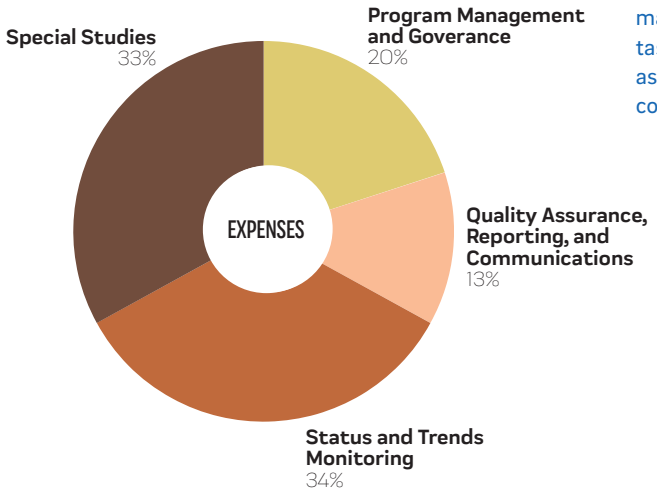
RMP FEES BY SECTOR: 2020

The fees target for 2020 was $3.80 million.

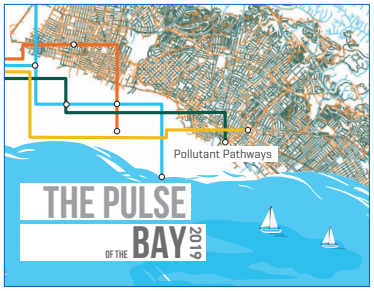


RMP EXPENSES: 2020

RMP expenses in 2020 were 34% for status and trends monitoring, 33% for special studies, 20% for program management and governance tasks, and 13% for quality assurance, reporting, and communications.



COMMUNICATIONS



Includes the *Pulse of the Bay*, Annual Meeting, Multi-Year Plan, State of the Estuary report, RMP website, Annual Monitoring Report, technical reports, journal publications, 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 1.2 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.

CONTAMINANT DATA DISPLAY & DOWNLOAD
cd3.sfei.org

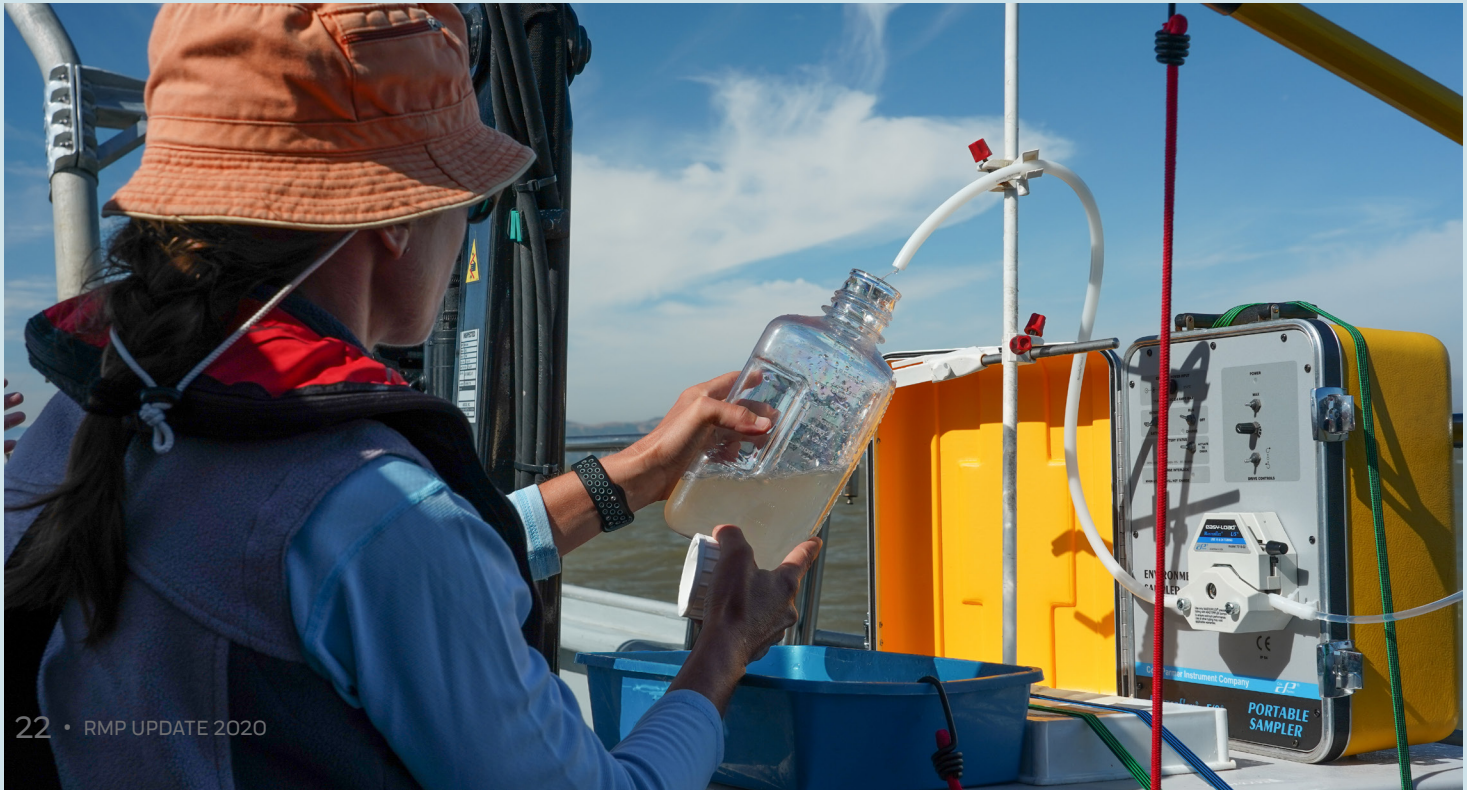
FEATURED PROJECT
Status and Trends Program Review

· BY DR. MELISSA FOLEY, SFEI

Status and Trends Monitoring: A Cornerstone of the RMP

The Status and Trends (S&T) Program (full description of the Program on page 38) is a vital component of the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). The S&T Program represents a large annual investment and a huge investment over the long term. The RMP spends about one third of its annual $4 million budget on the S&T Program every year, and $30 million has been spent on the S&T Program over the last 20 years. Monitoring in the current S&T Program is almost exclusively focused on legacy contaminants, including mercury, PCBs, PAHs, dioxins, copper, and selenium. While these contaminants are still of concern in the Bay and important to monitor, contaminants of emerging concern (CECs) are becoming a higher priority for the RMP based on the growing list of CECs that have been classified as Moderate Concern (due to a high probability of some impact on Bay aquatic life) using the Program's tiered risk-based prioritization framework and a desire on the part of managers to focus on a more proactive approach to protecting Bay water quality.

Peer review is essential to the success of the RMP, ensuring the Program is technically sound and obtaining the greatest value for the funds that are invested (Trowbridge et al. 2015). Since it is a multi-decadal effort, the S&T Program is reviewed on a longer schedule than the shorter-term studies conducted under the other major program area: Special Studies. RMP S&T monitoring has evolved considerably since the Program began in 1993, striving to make optimum use of RMP funds in response to advances in understanding of status and trends for pollutants of concern and changing information needs of water quality managers.



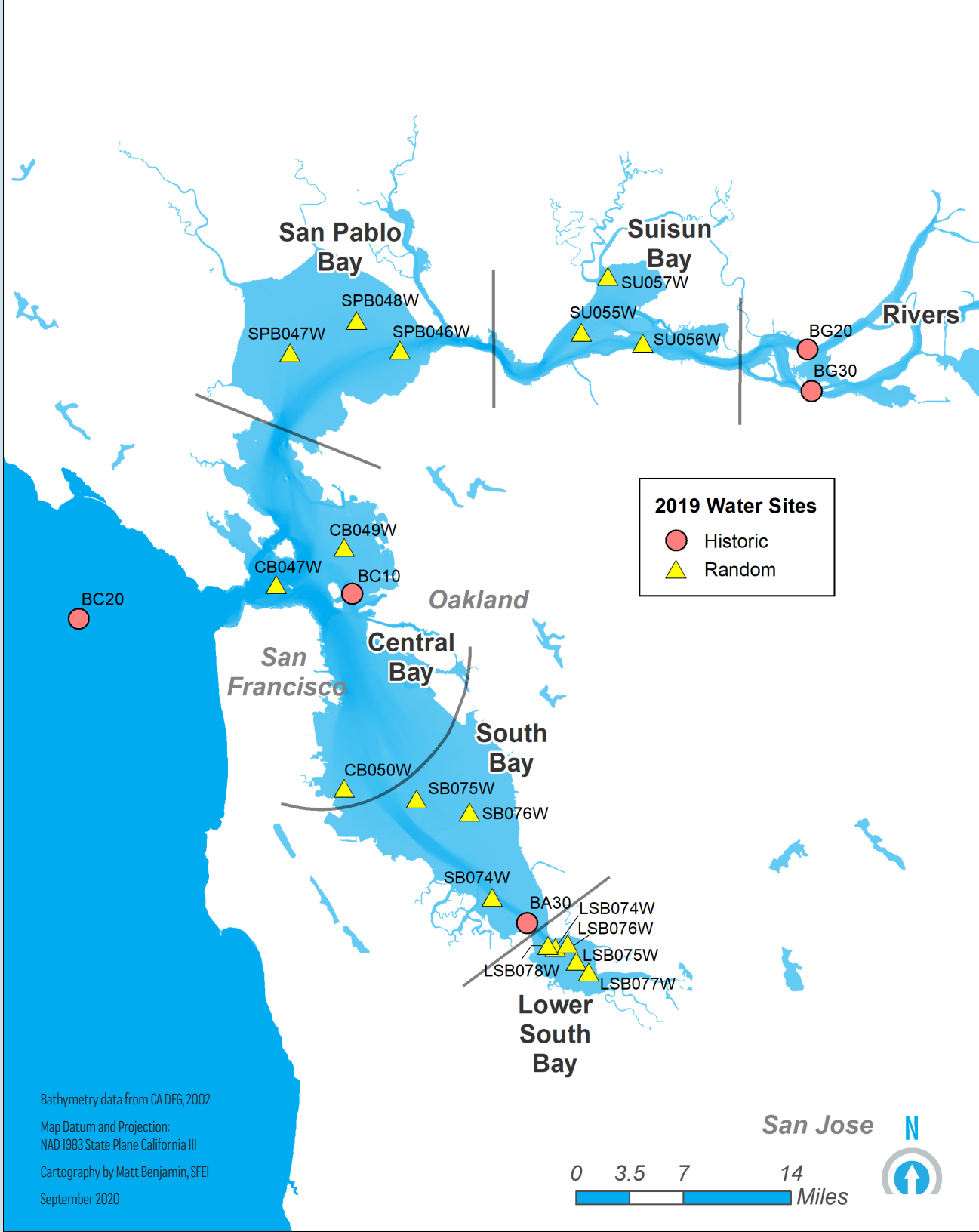
Author Dr. Melissa Foley, Senior Scientist at SFEI, and RMP manager, collecting a sample of Bay water. Photograph by Shira Bezalel.

Contaminants of emerging concern (CECs) are becoming a higher priority for the RMP

Past Evolution of the S&T Program

The last full review of the S&T Program was completed in 2002, and resulted in fundamental changes to the spatial distribution of stations, as well as the timing and frequency of sampling for water and sediment. The original S&T Program—from 1993 to 2001—included fixed location stations that were repeatedly sampled three times a year for water, and two times a year for sediment and bivalves. Stations were distributed throughout the Bay, including Lower South Bay, the main shipping channel outside the Golden Gate (water only), and near river inputs in San Pablo Bay, Carquinez Strait, and the Delta (map of original sampling design). As part of the first review process, the Bay was subdivided into hydrographic subembayments: Lower South Bay, South Bay, Central Bay, San Pablo Bay, Carquinez Strait, and Suisun Bay (Figure 1). The number of stations within each subembayment was determined by the management needs for specific contaminants and the power to detect differences from regulatory thresholds. The other major change resulting from the 2002 review was the introduction of probabilistic (i.e., random) sampling locations. Probabilistic sampling optimizes the ability to assess status because the spatial scale of sampling is expanded beyond fixed sites (map of sediment sites across years with multiple colored dots to show the non-overlapping,

Figure 1. Water sampling locations in 2019. ▶



random sites), making the monitoring results more representative of whole subembayments and the whole Bay than fixed stations.

Some historical stations were maintained for water and sediment for comparison across years. For the water matrix, five historical sites were retained and 28 random sites were monitored; sampling was decreased to once per year (dry season). Because water is a highly variable matrix, no repeat sites were recommended in the sampling design. For sediment, nine historical sites were retained and 40 random sites were monitored twice per year (wet and dry seasons). Because sediment is a more site-stable matrix than water, repeat visits for sites were included in the design, with some revisited every event, and others at longer intervals.

Additional adjustments were made to the Program in 2007, 2008, 2010, 2013, 2015, and 2020 as additional data were collected and reviewed, and management needs shifted.

▼ Changes to the S&T Program since the last major re-design in 2001.

Year	Water	Sediment	Bivalves	Bird eggs
2007	# of stations reduced from 31 to 22	# of stations reduced for winter sampling from 47 to 27 stations, added benthos		Added to the Program
2008	New management question framework			
2010	Sampling frequency reduced to biennial	Sampling frequency reduced to once per year, alternating between dry and wet season, 27 stations		
2013		Reduced to quadrennial sampling, dry season only		
2015		Added margins sediment		
2020			Discontinued monitoring	

◀ Collecting a water sample for chlorophyll analysis. Photograph by Shira Bezalel.

▼ The current S&T Program.

	Matrices			
	Water	**Sediment**	**Bird eggs**	**Sport fish**
# of sites	22	27 (open Bay) 40 (margins)	3	7
Season	Summer	Summer	Summer	Summer
Key analytes	Copper, selenium, California Toxics Rule list	Mercury, PCBs, PAHs, metals	Mercury, PCBs, selenium, PFCs, dioxins	Mercury, PCBs, selenium, PFCs, dioxins
Uses	303(d) list, NPDES permits, CEC screening	TMDL progress, dredged material regulation, CEC screening	TMDL progress, tracking non-TMDL contaminants, CEC screening	TMDL targets, fish advisory, CEC screening

The Present S&T Program

As of 2020, the S&T Program consists of four matrices—water, sediment, bird eggs, and sport fish—that are monitored every two (water), three (bird eggs), four (sediment), or five (sport fish) years. Each of these matrices will be reviewed to ensure the design meets management needs and is cost effective.

Charting a Course for the Future

The overarching goal of the review effort is to set RMP S&T monitoring on a solid course so the $30 million invested over the next 20 years yields as much information as possible to support decisions about managing Bay water quality.

Additional goals of the S&T Program review include:

1. ensuring the Program is generating information that is relevant to management needs;
2. evaluating the power of the current sampling design to inform management decisions; and
3. developing an optimized design that prioritizes informing management decisions for CECs.

The S&T Program Review, which started in April 2020, is being conducted by a S&T Workgroup that includes eight external science advisors with extensive expertise in long-term monitoring programs, CECs and legacy contaminants, and statistical analysis (Sidebar). The advisors are working in collaboration with RMP staff and stakeholders to review the existing Program, perform statistical analyses, and define sampling priorities to inform the updated design. The S&T Program will be reviewed by matrix: water, sediment, and biota. Data generated since 2002 for these matrices will be reviewed to assess past and future performance, and CEC monitoring will be added to the S&T Program in a manner that takes into account CEC pathways, chemical properties, toxicity thresholds, and existing data. CECs may be added to the Program incrementally to collect additional information necessary to inform a design that efficiently answers management questions.

In addition to the broad goals of the review, a list of review priorities specific to each matrix has also been developed. For all matrices, we want to evaluate the cost-effectiveness of the Program as well as review how the ability to address management needs is affected by changes in analytical labs or methods.

For water, we will evaluate the need for reinstating wet season sampling, particularly as CECs are included in the Program. Some CECs are

The S&T Science Advisors

Tom Grieb, Chair,
Tetra Tech

Dr. Grieb is a chief scientist in Tetra Tech's Water Group with 40 years' experience. He recently served as project manager for technical efforts that supported the preparation of the Selenium (Se) TMDL by the California Regional Water Quality Control Board. This work included source characterization and Se loading assessment, the development of a conceptual model of the processes that affect Se biogeochemistry, and the modeling of Se fate and transport in the San Francisco Bay-Delta. He has participated in similar projects for mercury and copper in the Bay-Delta. His primary research interests include the behavior of metals in the aquatic environment and the application of statistical methods to characterize uncertainty in environmental data sets and simulation models.

Margaret Dutch, Sediment,
Washington Department of Ecology

Maggie Dutch is the lead scientist for the Washington State Department of Ecology's Marine Sediment Monitoring Team. She has been with this team since 1992, studying sediments and benthos for the Puget Sound Sediment Monitoring Program. Maggie focused on marine invertebrates as an undergraduate at the University of New Hampshire, and polychaete taxonomy and benthic ecology for her MS from the University of Hawaii. Before moving to Washington, Maggie monitored sediments and benthic communities with the City of San Francisco's ocean outfall monitoring team. She currently lives in Olympia, and can't live without rain, clouds, and Puget Sound vistas.

James Meador, Biota, NOAA
Northwest Fisheries Science Center

Dr. Meador is an environmental toxicologist with NOAA Fisheries in Seattle. He has worked more than 35 years in the field and has extensive experience studying bioavailability, bioaccumulation, toxicokinetics, and toxic responses in animals ranging from worms to whales. He has also examined the use of tissue residues of various chemicals as the dose metric and its utility for toxicity assessment, monitoring, and environmental quality guidelines. Jim is currently studying the effects of metabolic disruptors on aquatic species, especially from pharmaceuticals and personal care products. Recently he has used metabolomics and the fish plasma model to assess toxicity.

Erin Foresman, Bay-Delta Science,
State Water Resources Control Board

Erin Foresman is an Environmental Program Manager at the California State Water Resources Control Board (State Water Board) with 18 years of experience working on California water issues. She joined the State Water Board in 2017 and led a team through the final phase of Board approval of new standards for the Lower San Joaquin River to protect Chinook salmon. From 2002 to 2017, Erin was an Environmental Scientist at the US Environmental Protection Agency working on San Francisco Bay-Delta and wetlands regulatory issues. Erin is focused on providing accurate and accessible information about Bay-Delta water quality, water supply, and ecosystems and encouraging diverse voices to participate in California water conversation. Erin has a MS in Ecology from UC Davis, and a BS in Geology and BA in Communications from the University of Iowa.

Derek Muir, CECs, Environment and Climate Change Canada

Dr. Muir is a Senior Research Scientist with Environment and Climate Change Canada. His research has focused on persistent and bioaccumulative contaminants in aquatic environments including long-term trends in the Arctic and the Great Lakes. He has been an advisor for the RMP Emerging Contaminants Workgroup since 2006. He is a Fellow of the Society of Environmental Toxicology and Chemistry, and a Fellow of Canada's national academy, the Royal Society of Canada. He is author or co-author of about 700 peer reviewed papers, book chapters, and assessment reports and is ranked among the top 1% most cited in the field of Environmental Science/ Ecology.

Lisa Nowell, Sediment and CECs, USGS National Water Quality Program

Dr. Nowell is a research chemist with the U.S. Geological Survey's California Water Science Center. Her current research focuses on characterizing pesticide mixtures in streams, evaluating effects of contaminants and other stressors on stream communities, and developing and refining benchmarks and other tools for assessing effects of contaminants. She has a B.A. in human biology (Stanford University), and an M.S. in ecology and Ph.D. in agricultural and environmental chemistry (University of California, Davis). Lisa currently is an Associate Editor of Human and Ecological Risk Assessment: An International Journal, Editorial Board member for Environmental Toxicology and Chemistry, and Science Advisor for the Delta Regional Monitoring Program. She served on the 2019 EPA FIFRA Science Advisory Panel on Approaches for Quantitative Use of Surface Water Monitoring Data in Pesticide Drinking Water Assessments.

Harry Ohlendorf, Biota, Independent

Dr. Ohlendorf has 48 years of experience in evaluating the impacts of environmental contaminants on wildlife in aquatic and terrestrial ecosystems, including 30 years at CH2M HILL (now Jacobs) and more than 18 years with the U.S. Fish and Wildlife Service. His experience includes a wide variety of environmental projects, including the occurrence and impacts of contaminants in aquatic and terrestrial ecosystems; planning, implementation, and reporting of site ecological characterizations and surveys; contaminant exposure and effect analyses; risk characterizations; and project impact evaluations. Many projects have focused on selenium and on the Bay Area watershed.

Tony Olsen, Statistician, US EPA

Anthony R. Olsen is a research mathematical statistician in the Pacific Ecological Systems Division at the U.S. Environmental Protection Agency in Corvallis, Oregon. As an environmental statistician, he specializes in survey design and analysis of large–scale aquatic monitoring studies. His research focuses on survey design and analysis methodology for sampling natural resources in geographic space. A particular interest is the development of spatially-balanced survey designs, including computer software to implement survey designs and subsequent statistical analyses of their results. He received his PhD from Oregon State University and his MS and BS from University of Wyoming, all in the field of statistics.

predominantly delivered to the Bay via stormwater runoff, so concentrations measured in the dry season may not be reflective of conditions when the influence of stormwater is greatest. The location of stations will also be reviewed, particularly the distribution of stations across subembayments and the possible addition of fixed locations that are close to CEC pathways to the Bay.

Finally, we will review the frequency of toxicity testing. Currently, water for toxicity testing is collected at nine sites on every cruise. Since collection of these samples started in 1994, 5% of tests (29 of 583 tests) have shown significant toxicity, and the last sample to do so was collected in 2011.

For sediment, we will review the "triad" testing approach that includes chemistry, toxicity, and benthic community assessment. The value of the triad approach has been reviewed by other long-term monitoring programs (e.g., Puget Sound) and may not offer a coherent assessment of sediment condition. The 2002 sediment monitoring design included site revisits over time; this will be evaluated to determine if it is providing the expected information. Finally, the inclusion of margin areas in the regular sediment monitoring program will be considered. Samples from the third and final margins segment of the Bay for a margins pilot study were collected in summer 2020.

For biota, the S&T Workgroup will evaluate the necessity of including additional biota in the program, such as harbor seals, which have been monitored in prior RMP CEC studies because they are good integrators of persistent emerging contaminants. The recent decision to discontinue bivalve monitoring will also be revisited. An alternate design may include bivalves collected from shoreline locations, which may be more relevant to the primary use of these data as an oil spill baseline indicator.

The overarching goal of the review is to set RMP S&T monitoring on a solid course so the $30 million invested over the next 20 years yields as much usable information as possible

Based on the goals of the review and the priorities for each of the matrices, possible changes to the Program include adding wet season sampling for CECs in water, changing the spatial distribution of stations and their proximity to potential pathways, and reducing the frequency of monitoring for persistent legacy contaminants (e.g., PCBs) and toxicity. The new design will be constrained by available funding as well as the availability of research vessels, which has been an increasing challenge for the RMP.

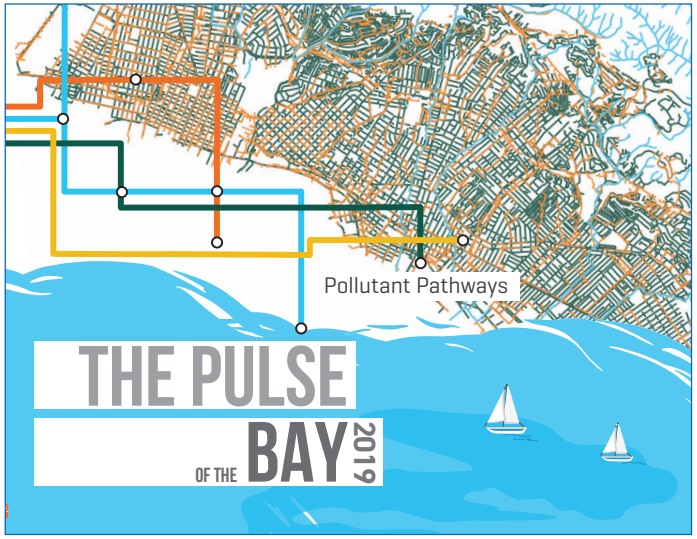
The S&T Workgroup will meet five times over the next year to develop the revised S&T design. One meeting will be devoted to each matrix, with the last two meetings reserved for synthesizing the recommendations and developing an integrated design for the Program as a whole. The review is expected to be completed by December 2021. In 2022 a new chapter of RMP Status and Trends monitoring will begin, with a design that enhances the ability of water quality managers to proactively detect and prevent emerging threats while maintaining our ability to track progress on the persistent problems of the past. §

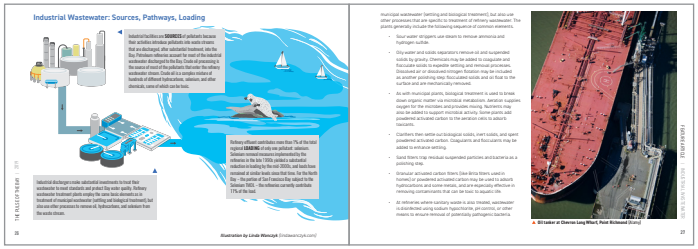
Measuring a volume of sample water for filtration. Photograph by Shira Bezalel. ▶

Recent **Publications**

The Pulse

The Pulse of the Bay: Pollutant Pathways. SFEI. 2019. https://www.sfei.org/rmp/pulse





Journal Publications

Multi-box mass balance model of PFOA and PFOS in different regions of San Francisco Bay. Soberón, F. Sánchez; Sutton, R.; Sedlak, M.; Yee, D.; Schuhmacher, M.; Park, J. - S. 2020. Chemosphere 252 . SFEI Contribution No. 986. https://www.sfei.org/documents/multi-box-mass-balance-model-pfoa-and-pfos-different-regions-san-francisco-bay

Sampling and Quality Assurance and Quality Control: A Guide for Scientists Investigating the Occurrence of Microplastics Across Matrices. Brander, S.M., Renick, V.C., Foley, M.M., Steele, C., Woo, M., Lusher, A., Carr, S., Helm, P., Box, C., Cherniak, S., Andrews, R.C., and Rochman, C.M. 2020. Applied Spectroscopy. DOI: 10.1177/0003702820945713

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Blurred lines: Multiple freshwater and marine algal toxins at the land-sea interface of San Francisco Bay, California. Peacock, M. B.; Gibble, C. M.; Senn, D. B.; Cloern, J. E.; Kudela, R. M. 2018. Harmful Algae 73, 138-147 . SFEI Contribution No. 875. https://www.sfei.org/documents/blurred-lines-multiple-freshwater-and-marine-algal-toxins-land-sea-interface-san-francisco

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2017 Update to Cyanide Rolling Average. Shimabuku, I. 2019. San Francisco Estuary Institute: Richmond, CA

Fact Sheets, Selected Posters and Presentations

New San Francisco Bay Contaminants Emerge. Sun, J.; Sutton, R.; Ferguson, L.; Overdahl, K. 2020. SFEI Contribution No. 931. https://www.sfei.org/documents/new-san-francisco-bay-contaminants-emerge

Find links to all presentations from the 2018 RMP Annual Meeting on the 2018 Annual Meeting webpage.

Find links to all presentations from the 2019 RMP Annual Meeting on the 2019 Annual Meeting webpage.

Bottles for water samples. Photograph by Shira Bezalel. ▶

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Current-Use Pesticides, Fragrance Ingredients, and Other Emerging Contaminants in San Francisco Bay Margin Sediment and Water. Heberger, M.; Sutton, R.; Buzby, N.; Sun, J.; Lin, D.; Mendez, M.; Hladik, M.; Orlando, J.; Sanders, C.; Furlong, E. 2020. SFEI Contribution No. 934. San Francisco Estuary Institute: Richmond, CA. https://www.sfei.org/documents/current-use-pesticides-fragrance-ingredients-and-other-emerging-contaminants-san-francisco

Expert review of the sediment screening guidelines for the beneficial reuse of dredged material in San Francisco Bay. Foley, M.; Christian, E.; Goeden, B.; Ross, B. 2020. SFEI Contribution No. 978. San Francisco Estuary Institute: Richmond, CA. https://www.sfei.org/documents/expert-review-sediment-screening-guidelines-beneficial-reuse-dredged-material-san

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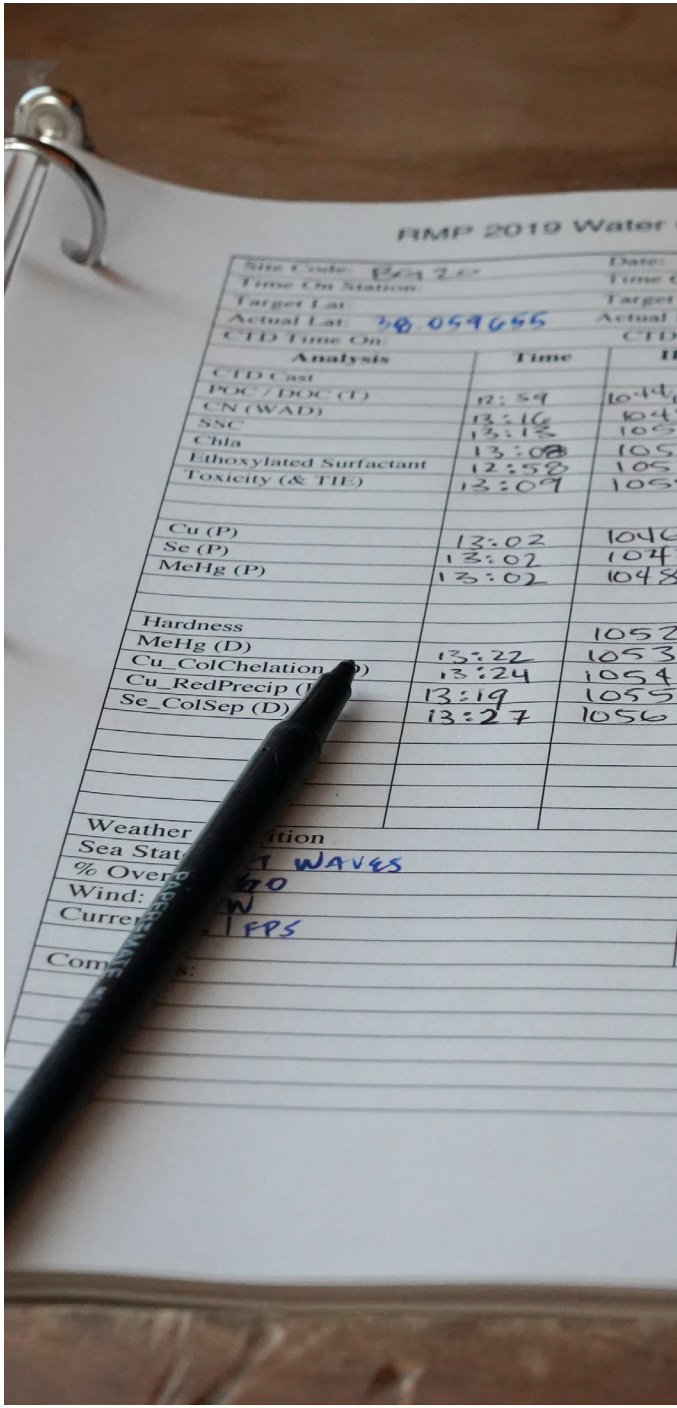


Water cruise field data sheet. Photograph by Shira Bezalel. ▶

Published Datasets

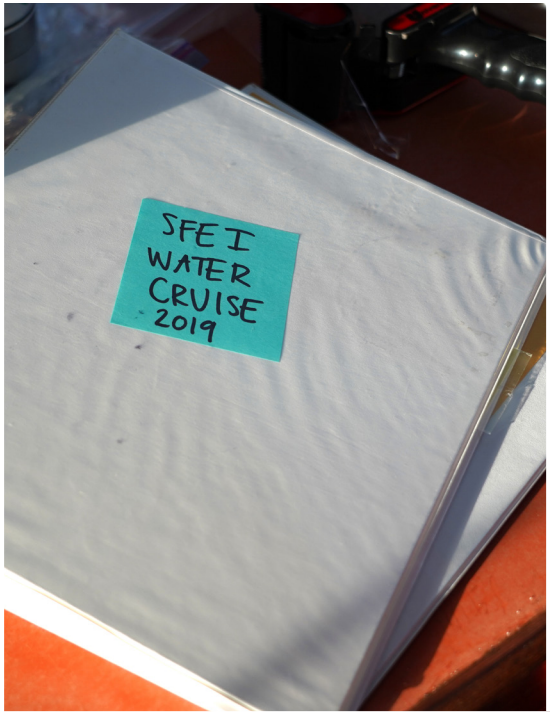
The RMP datasets that were finalized in the last two years are listed below. These datasets are available on cd3.sfei.org. To download the dataset, click on "Direct Download Tool" and select the associated Project Code and Analyte Group.

Dataset	Project Code
2018 RMP Bird Eggs	Conventional, Flame Retardants, Metals, PCBs, PFAS
2018 RMP Status and Trends Bivalves	2018 RMP Status and Trends Conventional, endpoint, metals, PAHs
2018 RMP Status and Trends Sediment	2018 RMP Status and Trends Conventional, FlameRetardants, Metals, PAHs, PCBs, Pesticides
2019 Priority Margin Unit (PMU)	2019 PMU Water Chemistry Conventional, PCBs
2019 Status and Trends Toxicity	2019 RMP Status and Trends Water Toxicity and Chemistry Endpoint, Conventional, Metals

Collecting water for toxicity testing. Photograph by Shira Bezalel.. ▶

PROGRAM AREA UPDATES

STATUS AND TRENDS



BACKGROUND

The Status and Trends 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 tissues have been monitored regularly in the open Bay. Sport fish and bird egg monitoring were added to the Program in 1997 and 2007, respectively.

Annual sampling of water and sediment had sufficiently documented trends and spatial patterns that varied by pollutant. This led to a revision between 2011 and 2014 to free up resources for special studies and other topics.

Sediment monitoring in the shallow margin areas of the Bay is currently being considered for addition to the Status and Trends program. Pilot studies were completed in Central (2015) and South (2017) Bays in 2015 and 2017, respectively; the pilot work will be completed in 2020 with sampling in North Bay.

RELATION TO PERMIT REQUIREMENTS

NPDES 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

1. What are the concentrations and masses of priority contaminants in the Bay, its compartments, and its segments?
2. Are contaminants at levels of concern?
3. Are there particular regions of concern?
4. Have concentrations and masses increased or decreased?
5. What are the associated impacts of those contaminants?

RECENT FINDINGS

In 2017, the RMP monitored PCBs, mercury, and other contaminants in sediment in the margin areas of South Bay. Contaminant concentrations were lower in South Bay margins than Central Bay margins, likely due to fewer industrialized areas in South Bay. There was also less of a difference between the margins and open Bay sites in South Bay than Central Bay. In South Bay, the margins make up a large portion of the area and are in closer proximity to open Bay areas than margins in Central Bay, leading to more uniform mixing of contaminants.

Copper concentrations in water, last monitored in 2019, remain below trigger levels. An inconsistency between two analytical methods (a new method and the method used in prior years) that was noted in 2017 was still present in 2019. Additional work will be done in 2021 to determine why this discrepancy persists.

Sport fish samples were collected in the summer of 2019 and are currently being analyzed. The coronavirus pandemic and shelter in place order for California came just before all tissues could be processed. Results are anticipated from the labs by early fall.

Bivalve monitoring was suspended for 2020 pending further discussion of this element during the Status and Trends Review. The data generated were not addressing priority management information needs. We are coordinating with other agencies that are interested in the data to shift the program to shore-based sampling that leverages sampling of bivalves for harmful algal toxins.

WORKPLAN HIGHLIGHTS

Long-term monitoring of

- nutrients, monthly
- water every two years,
- bivalves every two years (discontinued in 2020; sampling at locations around the edge of the Bay will be assessed during the S&T Review (see Featured Project on page 22),
- bird eggs every three years,
- sediment once every four years, and
- sport fish once every five years

In 2019, the RMP monitored water and sport fish. A report summarizing the results of the sport fish monitoring will be completed in 2021. The water monitoring data will be reported in the 2021 Pulse of the Bay.

In 2020, the RMP is finishing the third and final sampling area for margin sediment - North Bay - with stations located in San Pablo Bay, Carquinez Strait, and Suisun Bay. A report summarizing the results of this study, and comparing them results from the margin areas of Central and South Bay, will be completed in 2022.

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. The pandemic interrupted sampling between March and July, but sampling is again underway.

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
- Pacific EcoRisk
- Moss Landing Marine Laboratory
- Marine Pollution Studies Laboratory
- Coastal Conservation & Research
- City of San Jose

EMERGING CONTAMINANTS

BACKGROUND

Contaminants of emerging concern (CECs) are generally not actively regulated or 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. Surveillance has identified several contaminants or contaminant classes of moderate concern:

- PFAS — stain and water repelling chemicals widely used in industrial and consumer products;
- fipronil and imidacloprid — insecticides with widespread urban uses;
- alkylphenol and alkylphenol ethoxylates — detergent ingredients;
- bisphenols — plastic additives; and
- organophosphate esters — flame retardants and plasticizers.

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.
- The most recent Municipal Regional Stormwater Permit (2015) requires monitoring studies of key CECs, including flame retardants, PFAS, and pesticides.

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 Initiative
- DTSC Safer Consumer Products Program

PRIORITY QUESTIONS

1. Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay?
2. What are the sources, pathways, and loadings leading to the presence of individual CECs or groups of CECs in the Bay?
3. What are the physical, chemical, and biological processes that may affect the transport and fate of individual CECs or groups of CECs in the Bay?
4. Have the concentrations of individual CECs or groups of CECs increased or decreased in the Bay?
5. Are the concentrations of individual CECs or groups of CECs predicted to increase or decrease in the future?
6. What are the effects of management actions?

RECENT FINDINGS

In 2020 the RMP prepared an update of its CEC Strategy. The update described the addition of recently monitored CECs to the tiered risk-based framework, a prioritization framework used to classify the level of concern associated with emerging contaminant compounds or classes. Information regarding environmental persistence as a secondary factor when classifying CECs within the framework was added. A revised multi-year plan and recommendations for Status and Trends monitoring were also provided.

The 2020 CEC Strategy update also outlines an approach for evaluating the potential toxicological risks of data-poor contaminants. Identifying toxicological thresholds for CECs should first use the best available in vivo data, then in vitro data when in vivo data are unavailable, and model predictions when in vitro data are unavailable. Predictive in vitro screening of environmental samples may help identify when mixture effects or additional, unmeasured contaminants are a concern for aquatic life.

A recent pro bono investigation of quaternary ammonium compounds (QACs) in Bay sediment found detectable levels of several QACs, which are commonly used antimicrobials. Notably, the highest concentrations were found in Grizzly Bay, suggesting a localized source, and Lower South Bay, an embayment impacted by municipal wastewater discharges. A sediment core from Central Bay, spanning roughly 60 years of sediment deposition (1951-2009), had QACs in each of the seven layers tested. The concentration profiles suggest a declining temporal trend. However, because of the COVID-19 pandemic and the major use of QACs as antimicrobial active ingredients, use of these compounds has likely increased significantly. As a result, the RMP has launched a special study analyzing QACs in wastewater as well as stormwater and sediment.

An evaluation of RMP monitoring data on per- and polyluoroalkyl substances (PFAS) with respect to both toxicity and persistence in the environment led to the elevation of this class to Moderate Concern in the Bay. To date, much of the regulatory focus for PFAS has been on drinking water; however, the State Water Board, in coordination with Regional Water Boards, recently released interim final Environmental Screening Levels for perfluorooctanoic acid (PFOA) and perfluorooctanesulfonate (PFOS) for both aquatic habitat ecotoxicity and human exposure risk. These screening levels will allow better assessment of the risks posed by Bay water concentrations. The RMP and others are conducting PFAS monitoring in multiple matrices to develop the data needed to inform management of this important class of CECs.

WORKPLAN HIGHLIGHTS

Multi-year Monitoring Effort for CECs in Stormwater Continues: Findings from recent RMP non-targeted analysis has resulted in a new focus on unique and rarely studied contaminants derived from vehicles and roadways. A major effort to investigate these and other CECs in Bay Area stormwater continues this fall.

New Strategy for Assessing Toxicity Thresholds will Improve Assessment of Data-poor CECs: A synthesis and assessment of the quality of the available thresholds for CECs detected in the Bay in the past ten years is now underway to inform design of future monitoring. The synthesis will include calculating or estimating thresholds for data-poor CECs using predictive toxicology methods and risk screening for the Bay using a risk characterization ratio approach. The estimation and compilation of toxicity thresholds may support recategorization of some CECs currently classified as Possible Concern due to insufficient toxicity data.

Fresh Examination of PFAS in Bay Water: In summer 2021, the RMP will monitor concentrations of PFAS in Bay water and compare them to results from previous RMP monitoring in 2009. Improved analytical methods will provide a first look at a broader range of analytes. Findings will elucidate risks posed by a broader array of PFAS and inform the State Water Board's statewide investigation of this important class of emerging contaminants.

COLLABORATORS

- Bay Area Clean Water Agencies
- California Department of Toxic Substances Control
- California Department of Pesticide Regulation
- Duke University
- Jinan University
- SGS AXYS
- San Francisco Bay Regional Water Quality Control Board
- San Diego State University
- Southern Illinois University
- Southern California Coastal Water Research Project
- TDC Environmental
- University of Minnesota
- US Geological Survey

SMALL TRIBUTARY LOADING

BACKGROUND

San Francisco Bay PCB and mercury TMDLs were established to address health risks to humans and wildlife. Urban tributary loads are named in the TMDLs as the primary controllable pathway for reducing impairment. Other pollutants of concern (POCs) in urban stormwater include copper, nutrients, pesticides, emerging contaminants, and microplastics.

To address information needs associated with these POCs, the Small Tributaries Loading Strategy (STLS), first developed in 2009, was updated in 2018 to include a trends component to help prioritize and coordinate the activities of the RMP and Bay Area Stormwater Management Agencies Association permittees. STLS studies conducted over the past decade have been focusing on locating, quantifying, and managing PCBs, mercury, and other pollutants in the urban environment to support management actions. Going forward, an increasing emphasis will be placed on emerging contaminants, along with tracking trends in POC loading and best management practice (BMP) implementation progress, through a combination of monitoring and modeling.

USES OF PROGRAM AREA DATA FOR MANAGEMENT DECISIONS

- Refining pollutant loading estimates for future TMDL updates
- Informing provisions of the current and future versions of the Municipal Regional Stormwater Permit (MRP)
- Identifying small tributaries to prioritize for management actions
- Informing decisions on the best management practices for reducing pollutant concentrations and loads
- Tracking effectiveness of load reduction in individual small tributaries

RELATION TO PERMIT REQUIREMENTS

Addresses monitoring requirements specified in the Municipal Regional Stormwater Permit

- Pollutants of Concern and Emerging Contaminant Monitoring
- Wet Weather Pesticides and Toxicity Monitoring
- Implement Control Measures to Achieve Mercury/ PCB Load Reductions
- Assess Mercury/PCB Load Reductions from Stormwater
- Plan and Implement Green Infrastructure to Reduce Mercury/PCB loads
- Prepare Implementation Plan and Schedule to Achieve TMDL Allocations

PRIORITY QUESTIONS

1. What are the loads or concentrations of pollutants of concern from small tributaries to the Bay?
2. Which are the "high-leverage" small tributaries that contribute or potentially contribute most to Bay impairment by pollutants of concern?
3. How are loads or concentrations of pollutants of concern from small tributaries changing on a decadal scale?
4. Which sources or watershed source areas provide the greatest opportunities for reductions of pollutants of concern in urban stormwater runoff?
5. What are the measured and projected impacts of management action(s) on loads or concentrations of pollutants of concern from the small tributaries, and what management action(s) should be implemented in the region to have the greatest impact?

RECENT FINDINGS

Winter storm sampling by the RMP and the Bay Area Stormwater Management Agencies Association (BASMAA) has been conducted in 88 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, Santa Fe Channel in Richmond, Pulgas Pump Station-North in San Carlos, Gull Drive storm drain in South San Francisco, and an outfall at Gilman Street in Berkeley. The outfall at Gilman Street and the Santa Fe Channel sites also appear to have relatively high concentrations of mercury.

Remote sediment sampler testing at 14 sites is now complete and proven as a useful lower-cost stormwater characterization tool, especially for PCBs. These samplers were used for characterizing stormwater concentrations on particles at new sites in Water Year 2019, and will continue to be utilized in Water Year 2021 (none of the sites in Water Year 2020 were appropriate for remote sediment samplers) .

Reconnaissance data collected during single storms have provided evidence to support enhanced management efforts in watersheds with high PCB concentrations in water and on sediment particles. However, sources have not been located in all watersheds exhibiting high concentrations and data have had limited value for prioritizing management efforts in watersheds exhibiting moderate or lower concentrations, yet these watersheds likely contain patches with elevated concentrations. In 2018, the RMP explored advanced data analysis methods based on loads and yields and PCB congener patterns to add additional information to support management decisions. With method development complete (2018 funding), the loads and yields methods were applied with 2019 and 2020 funding to data from over 140 watersheds and the congener analysis method was applied in 75 watersheds. Ranking based on this analysis revealed some sharp contrasts to those based on concentrations and particle ratios.

WORKPLAN HIGHLIGHTS

Stormwater Reconnaissance Sampling: Over the past six years, the RMP, in collaboration with BASMAA member agencies, has funded watershed reconnaissance to support a weight-of-evidence approach for the identification and management of PCB and mercury sources. This effort will continue, providing data on concentrations in water and on sediment particles to identify high-leverage watersheds and subwatersheds within larger areas of older urban and industrial land use. To decrease costs and increase ease of data collection, remote samplers will be used in new sample locations while manual composite sampling methods will be primarily used to revisit previously sampled locations.

Trends Strategy and Regional Model Development: The evaluation of stormwater loading trends in relation to management efforts and beneficial use impacts is an important new focus. To support this focus, the STLS trends strategy was updated in 2018 and expanded to outline a multi-year plan to assess trends in regional PCB loads over decadal scales through a combination of modeling and monitoring. An initial step was to develop a detailed Modeling Implementation Plan, completed in 2019. In 2020, the first stage of modeling, developing a hydrologic model for the Bay, was initiated with input and oversight by STLS and the SPLWG. A sediment model will be developed in 2021.

Integrated Watershed Modeling and Monitoring Implementation Strategy: As the focus of modeling moves towards assessing a broader suite of contaminants including sediment, nutrients, and emerging contaminants, the monitoring required to model contaminant groups with similar characteristics (chemical and physical properties, sources, pathways, etc.) needs to be systematically identified, and the model structure to support these priorities needs to be identified. The RMP integrated watershed modeling and monitoring strategy will address management questions related to watershed loading of a wide array of POCs.

COLLABORATORS

- Bay Area Stormwater Management Agencies Association
- SGS AXYS
- San Francisco Bay Regional Water Quality Control Board
- US Geological Survey

NUTRIENTS

BACKGROUND

San Francisco Bay receives some of the highest nitrogen loads among estuaries worldwide, yet has not historically experienced the water quality problems typical of other nutrient-enriched estuaries. It is not known whether this level of nitrogen loading, which will continue to rise in proportion to human population increase, is sustainable over the long term. Special studies and expanded monitoring carried out through the RMP and the Nutrient Management Strategy have revealed some water quality conditions that have been associated with nutrient over-enrichment in other estuaries (e.g., recurring low dissolved oxygen in some margin habitats and consistent detection of multiple toxins produced by harmful algae). Potential impacts of these conditions on human and ecological health need to be more extensively evaluated and causal factors determined. A further complication is that the Bay's response to nutrients is influenced by many physical and biological factors including suspended sediment concentrations, light availability, freshwater inputs, and ocean conditions. These factors themselves vary by Bay subembayment and due to regional land and water management and climate oscillations. Therefore, a wide range of monitoring and special studies is needed to understand what might happen to Bay water quality as a result of changes in nutrients and other factors.

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

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.

PRIORITY QUESTIONS

1. What conditions in different Bay habitats would indicate that beneficial uses are being protected versus experiencing nutrient-related impairment?
2. In which subembayments or habitats are beneficial uses being supported? Which subembayments or habitats are experiencing nutrient-related impairment?
3. To what extent is nutrient over-enrichment, versus other factors, responsible for current impairments?
4. What management actions would be required to mitigate those impairments and protect beneficial uses?
5. Under what future scenarios could nutrient-related impairments occur, and which of these scenarios warrant pre-emptive management actions?
6. What management actions would be required to protect beneficial uses under those scenarios?
7. 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?
8. 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?
9. What specific management actions, including load reductions, are needed to mitigate or prevent current or future impairment?

RECENT FINDINGS

Nutrient loads to San Francisco Bay are increasing. Combined nitrogen loads from the region's five largest wastewater treatment plants increased 25-30% between 2000 and 2018.

High-frequency sensors are providing continuous data at nine sites in South Bay and Lower South Bay. These data show that elevated phytoplankton biomass and low dissolved oxygen are frequently observed in Lower South Bay, and suggest that water from the salt ponds introduces high phytoplankton biomass into Lower South Bay sloughs and increases the potential for low dissolved oxygen events.

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 San Francisco Bay is a significant source of nutrients to the coastal ocean. However, data on how this input affects coastal condition is not available.

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

WORKPLAN HIGHLIGHTS

- Conducting experiments in South Bay to measure biogeochemical transformation rates
- 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
- Investigating the mechanistic link between nutrients and harmful algal toxins and blooms
- Developing trends analyses for key indicators of water quality
- Refining indicators and metrics that are included in the Assessment Framework for the deep subtidal areas of the Bay
- Expanding high-frequency monitoring on the dynamic shoals of the South Bay

COLLABORATORS

- San Francisco Bay Regional Water Quality Control Board
- Bay Area Clean Water Agencies
- Deltares
- San Francisco State University
- Stanford University
- UC Berkeley
- 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

SELENIUM

BACKGROUND

San Francisco Bay has been listed as impaired by selenium since 1990. Although water concentrations are below water quality thresholds, several wildlife species may be at risk for selenium toxicity. White sturgeon, a benthic species, is recognized as a key indicator of selenium impairment in the Bay due to its susceptibility to selenium bioaccumulation.

In 2016, a TMDL for the North Bay was approved, establishing numerical selenium targets for white sturgeon tissue and water. In addition, USEPA proposed criteria for selenium in Bay-Delta fish, clams, and water in June 2016. The RMP Selenium Workgroup was established in 2014 to develop monitoring strategies to inform implementation of the North Bay TMDL and consideration of a TMDL for the South Bay. Selenium in water, sediment, and tissue are also regularly monitored through RMP Status and Trends monitoring. A monitoring plan for a suite of indicators (including water, clams, and sturgeon) that can provide an early indication of changing selenium exposure in the North Bay was developed in 2018. Pilot implementation of this plan has been the focus of RMP special studies on selenium since 2019.

RELATION TO PERMIT REQUIREMENTS

- Supports the development and implementation of selenium TMDLs for North and possibly South Bay, as well as USEPA site-specific selenium criteria for the San Francisco Bay-Delta

USES OF PROGRAM AREA DATA FOR MANAGEMENT DECISIONS

- North Bay Selenium TMDL
- Proposed USEPA Selenium Criteria for the Bay-Delta
- South Bay Selenium TMDL (under consideration)

PRIORITY QUESTIONS

GENERAL

1. What are appropriate thresholds?
2. Are the beneficial uses of San Francisco Bay impaired by selenium?
3. What is the spatial pattern of selenium impairment?
4. How do selenium concentrations and loadings change over time?
5. What is the relative importance of each pathway of selenium loading in the Bay?

NORTH BAY

6. Are the beneficial uses of north San Francisco Bay impaired by selenium?
7. Are changes occurring in selenium concentrations that warrant changes in management actions?
8. Will proposed changes in water flows and/or selenium loads in the Bay or upstream cause impairment in the North Bay?

RECENT FINDINGS

Non-lethal monitoring of selenium in muscle plugs from white sturgeon (the species and tissue established as the impairment indicator in the TMDL) in 2015-2017 found that concentrations were significantly lower during the high flows of 2017 relative to the two prior drought years, confirming a pattern that was expected based on long-term monitoring of the clams that are a primary component of the sturgeon diet.

Sturgeon monitoring conducted in coordination with an annual sturgeon fishing derby in the western Delta, also in 2015-2017, showed that selenium concentrations in muscle are correlated with concentrations in ovaries and liver (tissues that are more closely linked to fish health risk), and that concentrations in muscle plugs are well correlated with concentrations in muscle fillets.

A selenium monitoring design for the North Bay was developed in 2018, and implementation of this plan began in 2019. The emphasis of the design is on early detection of changes that could warrant changes in management approaches.

Status and Trends monitoring has shown that Lower South Bay has higher average selenium concentrations in water than the other Bay segments, but white sturgeon collected in Lower South Bay have had lower concentrations than North Bay sturgeon. This difference from the North Bay may be due to the low abundance of *Potamocorbula* (overbite clam) in Lower South Bay.

WORKPLAN HIGHLIGHTS

- Implementation of the integrated monitoring design for Suisun Bay that includes water, clams, and sturgeon.
- Optimization of the monitoring design for selenium and other contaminants in the Status and Trends program as part of the Status and Trends design review.

COLLABORATORS

- Applied Marine Sciences
- Brooks Applied Labs
- California Department of Fish and Wildlife
- CalTest Laboratories
- San Francisco State University
- Tetra Tech
- UC Davis
- US Environmental Protection Agency
- US Geological Survey - Menlo Park

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 called for monitoring and management to focus on contaminated areas on the Bay margins. Local-scale actions within margin areas, or in upstream watersheds, will be needed to reduce exposure within these areas. The multi-year workplan for PCBs is focusing on supporting a possible revision of the PCBs TMDL 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 two margin areas that are high priorities for water quality managers: the Emeryville Crescent and San Leandro Bay. A site-specific conceptual model for a third area – Steinberger Slough – has also been completed.

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

- PCB TMDL and potential update
- Implementation of NPDES permits, including the Municipal Regional Permit for Stormwater
- Selecting management actions for reducing PCB impairment
- Updating the fish consumption advisory

PRIORITY QUESTIONS

1. What are the rates of recovery of the Bay, its segments, and in-Bay contaminated sites from PCB contamination?
2. What are the present loads and long-term trends in loading from each of the major pathways?
3. What role do in-Bay contaminated sites play in segment-scale recovery rates?
4. Which small tributaries and contaminated margin sites are the highest priorities for cleanup?
5. What management actions have the greatest potential for accelerating recovery or reducing exposure?
6. What are the near-term effects of management actions on the potential for adverse impacts on humans and aquatic life due to Bay contamination?

RECENT FINDINGS

Shiner surfperch have a Bay-wide average concentration nine times higher than the TMDL target, and 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 no clear sign of decline.

An assessment of Emeryville Crescent established a conceptual model as a foundation for monitoring response to load reductions and for planning management actions. The key finding was that PCB concentrations in sediment and the food web could potentially decline fairly quickly (within 10 years) in response to load reductions from the watershed.

A conceptual model for PCBs in San Leandro Bay was completed in 2018. A simple mass budget suggested that San Leandro Bay should respond to reductions in watershed loads, but sediment concentrations have not declined since 1998, suggesting that continuing inputs are slowing recovery. Significant cleanup actions that have been recently completed or are happening soon on highly contaminated properties adjacent to San Leandro Bay should promote recovery.

A conceptual model for the Steinberger Slough/Redwood Creek area was completed in 2020. The potential for PCB concentration reductions in this area appear to be much lower than in San Leandro Bay due to relatively high concentrations on suspended sediment particles in the adjacent open Bay.

WORKPLAN HIGHLIGHTS

- Baseline monitoring of four priority margin areas (Emeryville Crescent, San Leandro Bay, Steinberger Slough, and Richmond Harbor), beginning with shiner surfperch monitoring in 2019 (in coordination with the 2019 Status and Trends sport fish monitoring).
- Field studies to address critical information gaps and establish baselines for evaluating the effects of load reductions in Steinberger Slough/Redwood Creek (2020) and San Leandro Bay (2021).
- Writing a plan in 2021 for developing a model to forecast the fate of PCBs and other contaminants in the Bay, leveraging and integrating with models for nutrients, sediment, and watershed contaminant loads.

COLLABORATORS

- Moss Landing Marine Laboratory
- SGS AXYS Analytical
- Stanford University

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 microplastics. Recent legislation requires the California Ocean Protection Council to develop a state-wide microplastics strategy that articulates the risks from microplastics in marine waters and develop a mitigation strategy.

The San Francisco Estuary Institute recently completed a pioneering, three-year comprehensive regional study of microplastic pollution of a major urban estuary and adjacent ocean environment. This $1 million effort was primarily funded by the Gordon and Betty Moore Foundation, with additional funding and support provided by the RMP. Collaborators included science and advocacy organization 5 Gyres as well as scientists with the University of Toronto and University of California at Davis.

Findings were released at a one-day symposium, Science and Solutions for Microplastic Pollution, in October 2019. The symposium provided a summary of the state of the science in the morning. Afterwards, keynote speaker Jared Blumenfeld, Secretary for Environmental Protection, CalEPA kicked off a dynamic discussion of potential solutions and actions to address microplastic pollution. Major project deliverables included a 400 page report on the scientific findings, a document outlining policy recommendations and solutions, an action sheet for broad public distribution, and a short documentary film. The findings received significant media coverage; multiple peer-reviewed manuscripts are in preparation or have been submitted to scientific journals.

USES OF PROGRAM AREA DATA FOR MANAGEMENT DECISIONS

- State-wide microplastic strategy
- State-wide drinking water monitoring
- Regional or state bans on single use plastic items and foam packaging materials
- State and federal bans on microbeads
- Statewide trash amendments and requirements
- Municipal pollution prevention strategy using green stormwater infrastructure
- Public outreach and education regarding pollution prevention

RELATION TO PERMIT REQUIREMENTS

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

PRIORITY QUESTIONS

1. How much microplastic pollution is there in the Bay?
2. What are the health risks?
3. What are the sources, pathways, loadings, and processes leading to microplastic pollution in the Bay?
4. Have the concentrations of microplastic in the Bay increased or decreased?
5. What management actions may be effective in reducing microplastic pollution?

RECENT FINDINGS

Microplastics have been monitored in Bay surface water, sediment, prey fish, bivalves, and the adjacent ocean. Microplastics were ubiquitous, and the concentrations in Bay surface 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. Monitoring of municipal wastewater and urban stormwater identified urban stormwater to be the major pathway for microplastics. Urban stormwater samples were dominated by black rubbery fragments suspected to be from vehicle tire wear, as well as fibers. Fibers were the most frequently identified type of microparticle in wastewater, and wastewater facilities employing advanced treatment including dual media filtration had lower microparticle concentrations than facilities without this additional treatment, suggesting that enhanced treatment may reduce microparticles as well as other pollutants.

A novel three-dimensional hydrodynamic transport model was developed to simulate microparticle and microplastic movement in the Bay and the adjacent marine sanctuaries. The fate of microplastics discharged to the Bay was found to be highly sensitive to particle buoyancy, and even minimal sinking rates led to retention of particles within the Bay.

The field of microplastic pollution is in its infancy, and recommended best practices for future studies include the need for standard QA/QC practices such as collection of field and laboratory blanks, use of methods beyond microscopy to identify particle composition, and standardized reporting practices.

WORKPLAN HIGHLIGHTS

- **Development of a conceptual model of microplastic sources and pathways to urban stormwater.** Given the importance of urban stormwater as a pathway for microplastics in the environment, it is crucial to develop a conceptual understanding of the sources and sub-pathways for microplastics in urban stormwater to inform management actions that will reduce microplastics in San Francisco Bay. We will summarize available information to identify true sources and environmental release mechanisms, as well as possible factors influencing microplastic loads. The conceptual model will be used to identify priorities for research and initial mitigation activities, providing crucial support for Bay and state-wide microplastic strategies and informing management efforts that will be effective in preventing microplastic pollution.
- **Coordination with state-wide strategies.** The Bay microplastic strategy will continue to be developed in coordination with efforts to develop a state-wide microplastics strategy. This includes collaborating with the Southern California Coastal Water Research Project, State Water Board, and California Ocean Protection Council to convene world experts on microplastics to advance our understanding of human and ecotoxicological impacts of microplastics.

COLLABORATORS

- 5 Gyres Institute
- Bay Area Clean Water Agencies
- California Ocean Protection Council
- California State Water Resources Control Board
- City of Palo Alto
- East Bay Municipal Utility District
- Moss Landing Marine Laboratories
- Patagonia
- Plus M Productions
- San Francisco Baykeeper
- Southern California Coastal Research Project
- TDC Environmental
- University of Toronto
- University of Michigan

SEDIMENT

BACKGROUND

Sediment is a critical component of the Bay ecosystem. Sediment transport is a major factor in the fate and transport of priority pollutants such as PCBs and mercury. Sediment is also dredged from the Bay and disposed of in the Bay, which moves contaminants between locations, and sediment can be beneficially re-used in restoring wetlands or upland applications, removing contaminants from the Bay. Suspended sediment concentrations in Bay water also have an important role in controlling algae blooms by limiting light availability.

The RMP has been monitoring sediment 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 for mudflats, marshes, and other shoreline habitats to be able to vertically accrete to withstand the rising seas. As the San Francisco Bay Restoration Authority decides how to spend $500 million for habitat restoration over the next 20 years, it is critical to know how much sediment will be available and where it will be available.

In 2018, the RMP created a new Sediment Workgroup to bring together key stakeholders and scientists studying this issue and to prioritize studies to inform management decisions.

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

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

PRIORITY QUESTIONS

1. What are acceptable levels of chemicals in sediment for placement in the Bay, baylands, or restoration projects?
2. Are there effects on fish, benthic species, and submerged habitats from dredging or placement of sediment?
3. What are the sources, sinks, pathways, and loadings of sediment and sediment-bound contaminants to and within the Bay and subembayments?
4. How much sediment is passively reaching tidal marshes and restoration projects and how could the amounts be increased by management actions?
5. What are the concentrations of suspended sediment in the Estuary and its segments?

RECENT FINDINGS

The RMP funded a study in 2019 to compile more accurate estimates of the bulk density of Bay sediment so that sediment estimates can be converted between volume and mass with a higher level of certainty. The report compiles available data on sediment bulk densities across Bay habitats and along salinity gradients to provide better information for resource managers and others working on sediment-related issues.

A 2018 special study used PCB data in the Dredged Material Management Office (DMMO) database to estimate PCB concentrations in dredged sediment, compared that to ambient concentrations, and assessed the movement of PCBs within the Bay (to disposal sites) as well as removal from the Bay. PCB concentrations in dredged sediment monitoring tended to be higher than deep areas within the Bay but were similar to samples taken from the Bay margins. Approximately 50% of the PCB mass in dredged sediment is removed from the Bay via upland disposal.

In September 2019, the RMP funded a workshop to review the sediment guidelines for beneficial reuse. Four experts provided seven recommendations to update and improve the sediment guidelines used to determine if dredged sediment is appropriate for beneficial reuse.

WORKPLAN HIGHLIGHTS

- **Bathymetric change analysis.** Assessment of the changing bathymetry of the Bay is essential to understanding sediment dynamics. The RMP is funding the USGS to compile bathymetric data throughout the Bay and calculate bathymetric change over time. This work will also highlight the most pressing data gaps for Bay bathymetry.
- **Sediment flux at the Golden Gate.** Sediment flux through the Golden Gate is a major element of the overall sediment budget for the Bay The RMP is funding Anchor QEA to calculate sediment flux at the Golden Gate Bridge. The work will extend a previous model simulation through April 2017, a period coinciding with measurements made by the USGS showing net sediment flux into the Bay.
- **Integrated modeling and monitoring strategy.** A strategy document will highlight data gaps and priorities for modeling and monitoring throughout the Bay. The priorities identified in the document have been developed in collaboration with researchers and managers in the Bay, and provides a coordinated approach to doing sediment work in the Bay.

COLLABORATORS

- Anchor QEA
- San Francisco Bay Regional Water Quality Control Board
- US Environmental Protection Agency
- US Geological Survey - Santa Cruz
- US Geological Survey - Western Ecological Research Center

As the San Francisco Bay Restoration Authority decides how to spend $500 million for habitat restoration over the next 20 years, it is critical to know how much sediment will be available and where it will be available

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The end of the 2019 Water Cruise. Photograph by Shira Bezalel.

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