A Report of the Regional Monitoring Program for Water Quality in the San Francisco Estuary **2010**

THE PULSE OF THE ESTUARY

LINKING THE WATERSHEDS AND THE BAY

JON LEATHERBARROW

THIS EDITION OF *THE PULSE* is dedicated to the memory of Jon Leatherbarrow. Jon was a talented and dedicated colleague. He had diligently prepared himself to devote his career to reducing contaminants in stormwater and contributing to creation of a cleaner and greener Bay Area. Even more exceptional were Jon's qualities as a warm and supportive friend. In his short life Jon left a huge mark. We will remember him always.

COVER IMAGE
View from Grizzly Peak, Berkeley.
Photograph by Linda Wanczyk.

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LINKING THE WATERSHEDS AND THE BAY

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OVERVIEW: WATER QUALITY MONITORING: LINKING THE WATERSHEDS AND THE BAY

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Improving How We Live on the Land

The intimate linkage of San Francisco Bay with its surrounding watersheds is critical to the existence and health of the Bay. The rainwater that falls on the regional landscape flows down hillsides and through the urbanized lowlands, travelling toward the Bay in creeks, channels, and storm drains. Irrigation water that is pumped to households and farms from underground or from reservoirs near and far also follows these pathways to the Bay. The freshwater runoff pouring from the watersheds supplies the hundreds of mini-estuaries at the mouths of creeks and storm drains that contribute to the high productivity of the Bay ecosystem. This runoff also supplies sediment that forms the substrate on the bottom of the Bay, providing a home for many of the species that populate the Bay food web, and deposits in tidal marshes, helping these valuable habitats rise to keep pace with sea level.

Sample collection in Sausal Creek under the Alameda Countywide Clean Water Program. Photograph by Applied Marine Sciences.

Unfortunately, this close linkage also exposes the Bay to many hazards to the health of aquatic life and of humans that consume Bay fish and wildlife. In the words of Luna Leopold, the "health of our waters is the principal measure of how we live on the land." Many of our unhealthy habits on land, both past and present, have been a primary cause of the variety of water quality problems that afflict the Bay today. Our practices for use and disposal of chemicals in industry, commercial products, agriculture, and landscaping, along with fossil fuel combustion and waste management, all contribute to the impaired health of the Bay.

A Major Stride Forward

Early efforts to improve water quality in the Bay in the 1960s and 1970s focused on the treatment of municipal and industrial wastewater, and the investment of billions of dollars in this area resulted in dramatic reductions in emissions of pollutants into the Bay and elimination of the greatest water quality problems of the 1970s. In the late 1980s and 1990s, attention and investment shifted to less obvious water quality problems and the more elusive and diffuse sources of pollution in the Bay's watersheds. From the onset of these efforts, the San Francisco Bay Area has been recognized as a national leader in urban stormwater management. Over the past 20 years, Bay Area stormwater programs have received numerous national and state awards for efforts to manage stormwater and minimize related adverse impacts on water quality.

In 2009 the San Francisco Bay Regional Water Quality Control Board made another major stride forward in the management of urban stormwater through the adoption of a new Municipal Regional

> The health of our waters is the principal measure of how we live on the land–Luna Leopold

Stormwater Permit (MRP) that covers much of the Bay Area (page 8). The MRP has raised the effectiveness of stormwater management in the Bay Area to a higher level, providing a robust framework to ensure timely implementation of actions to prevent or control pollutants adversely impacting the Bay and its urban tributaries. The MRP accomplished this on a consistent regional basis through provisions that require a myriad of management actions (such as pump station monitoring, industrial facility inspection, low-impact development, control of illicit discharges, and public information and outreach); pollutant limitations to achieve cleanup goals for mercury and polychlorinated biphenyls (PCBs), additional limits for copper and pesticides, and an especially aggressive plan for trash reduction; and extensive monitoring in creeks and the Bay, in close coordination with the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP).

↑ A freshly stenciled storm drain. Photograph courtesy of Chris Sommers.

Monitoring in Support of Stormwater Management

In accord with the regulatory focus on pollutant transport from watersheds, understanding the influence of watersheds on the Bay has been a major emphasis of the RMP for the past several years, and this is planned to continue for at least the next five years. Our state of knowledge on contaminant loads from the watersheds is rudimentary, but growing rapidly. RMP studies conducted since 2003 have generated some of the first solid datasets on watershed loads of mercury, PCBs, and other contaminants (page 80) - these data are essential for implementation of Total Maximum Daily

OVERVIEW CONTINUED

Loads (TMDLs) and other management actions. RMP pilot studies in the Guadalupe River watershed and in a small, highly urbanized watershed in Hayward have shown that small tributaries contribute significant loads of sediments and pollutants to the Bay, changing the conventional wisdom of ten years ago that most loading came from the Central Valley. These studies also indicate that variation in loads among years is a complex function of annual runoff, rainfall intensity, sources, and area of impervious surface in a watershed.

The RMP has recently developed a Small Tributary Loading Strategy that lays out a plan for continuing to build needed datasets on watershed loads over the next five years (page 30). Initial work under the Strategy will develop a multi-year, overarching, coordinated blueprint for monitoring under the RMP and the MRP. The primary emphasis of the Strategy, with an RMP investment of over $1 million over the next four years, will be monitoring contaminant loads in carefully selected small tributaries. This information will be valuable in deciding which watersheds should be first in line for cleanup and in improving estimates of watershed loads at a regional scale.

Other Important Studies

Another important recent study evaluated ways to reduce loads of mercury and PCBs, two high priority contaminants in urban stormwater (page 20). Soil and sediment surveys indicate that mercury and PCBs are unevenly distributed in the urban landscape, suggesting that a strategy focusing on the most contaminated sites will be most effective. The study concluded that mercury may be best addressed through source control and maintenance, such as local air emissions control, mercury recycling, street sweeping, and drop inlet cleaning. For PCBs, the most promising management actions appear to be capture of mass during building demolition and treatment of high concentration soils and runoff from industrial areas.

Urban creeks are much more than conduits that carry runoff to the Bay – they provide valuable habitat for wildlife and also add great aesthetic value in the urban landscape. The Surface Water Ambient Monitoring Program (SWAMP) (page 68) is a statewide water quality monitoring program that has generated a large body of information on the health of urban creeks in the Bay Area. Unfortunately, these urban creeks are generally in poor condition. The SWAMP has also conducted extensive monitoring of contaminants in sport fish from Bay Area lakes and reservoirs, finding that methylmercury is elevated to some degree in all Bay Area reservoirs, not just those that were influenced by mining. A new website established by the California Water Quality Monitoring Council in collaboration with the SWAMP – My Water Quality – has greatly improved public access to water quality information generated for the Bay Area and the state as a whole.

Greener and Cleaner

Recent developments in stormwater management, in the Bay Area and across the nation, indicate a tremendous potential to transform our urban landscapes to make them greener, more water-conserving, and cleaner. The Municipal Regional Permit has accelerated the Bay Area's movement in this direction. The stage is set for another leap forward in improving water quality in San Francisco Bay.

The outlook is bright for solving the trash problem in the Bay and its creeks. Photograph by Cheri Donnelly.

TABLE OF CONTENTS

6 MANAGEMENT UPDATE

8
The Municipal Regional Stormwater Permit: Managing Municipal Stormwater Runoff in the San Francisco Bay Area

20
Promising Findings from a Study of Urban Stormwater Management Options

30
Linking the Watersheds and the Bay in the RMP: The Small Tributary Loading Strategy

42
The 303(d) List

43
Regulatory Status of Pollutants of Concern

44 STATUS AND TRENDS UPDATE

46
The Latest Monitoring Results

58
Water Quality Trends at a Glance

66 FEATURE ARTICLES

68
The Surface Water Ambient Monitoring Program: A View from the SWAMP

80
Tributary Loads: An Update on Large and Small Watersheds

94 REFERENCES AND CREDITS

95 RMP COMMITTEE MEMBERS AND PARTICIPANTS

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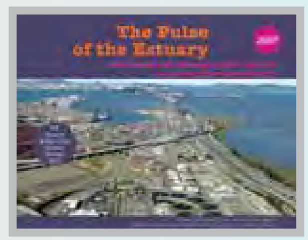

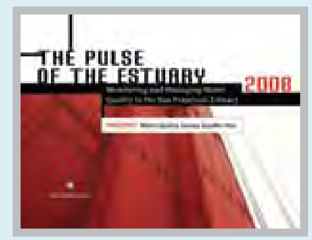

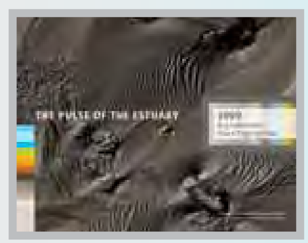

FOR PDF VERSIONS of the 2007, 2008 and 2009 editions of *The Pulse*, please go to www.sfei.org/rmp/pulse.

8 THE MUNICIPAL REGIONAL STORMWATER PERMIT: MANAGING MUNICIPAL STORMWATER RUNOFF IN THE SAN FRANCISCO BAY AREA

20 PROMISING FINDINGS FROM A STUDY OF URBAN STORMWATER MANAGEMENT OPTIONS

MANAGEMENT UPDATE

30 LINKING THE WATERSHEDS AND THE BAY IN THE RMP: THE SMALL TRIBUTARY LOADING STRATEGY

42 THE 303(D) LIST

43 REGULATORY STATUS OF POLLUTANTS OF CONCERN

↑ Views of Colma Creek. Photographs by Nicole David.

THE MUNICIPAL REGIONAL STORMWATER PERMIT: MANAGING MUNICIPAL STORMWATER RUNOFF IN THE SAN FRANCISCO BAY AREA

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Highlights

- Adoption of the Municipal Regional Stormwater Permit (MRP) in October 2009 was a significant milestone in management of urban runoff in the Bay Area
- The key goals of the MRP are to consolidate six permits into one consistent regional permit and to identify and implement specific management actions, monitoring, and reporting requirements
- The MRP governs a myriad of activities, such as pump station monitoring, industrial facility inspection, low-impact development (LID), control of illicit discharges, and public information and outreach
- The MRP limits pollutants, such as pesticides, trash, mercury, PCBs, and copper, with an especially aggressive plan for trash reduction
- The MRP also provides for prescriptive and expansive monitoring in creeks and the Bay, in close coordination with the Regional Monitoring Program

View from East Bay hills.
Photograph by Jon Leatherbarrow.

A Strong Framework

The San Francisco Bay Regional Water Quality Control Board (Water Board) achieved a significant milestone in its twenty year effort to regulate urban runoff when it issued the Municipal Regional Stormwater National Pollutant Discharge Elimination System (NPDES) Permit in October 2009. This permit, referred to as the MRP (or "merp" to insiders), replaces permits previously issued to individual municipalities in Alameda, Contra Costa, San Mateo, and Santa Clara counties, and the cities of Fairfield, Suisun City, and Vallejo in Solano County. The MRP covers 76 cities, counties, and flood management districts.

The MRP provides an efficient, consistent, and hopefully more effective regulatory mechanism to control pollutants in urban runoff, building on continuous improvements made via previous permits and actions by municipalities. Many components in the MRP were contained in the previous permits. Essentially, the MRP incorporates the level of detail and specificity of all of the stormwater management plans. Most important, the MRP provides a strong framework to ensure timely implementation of actions to prevent or control pollutants adversely impacting San Francisco Bay and its urban tributaries.

Background

Efforts to manage urban runoff quality in the Bay Area began with a call to action via an amendment to the Water Quality Control Plan for the San Francisco Bay Basin (the "Basin Plan") in November 1986. That plan established water quality objectives for several metals and other toxic pollutants with the recognition that the objectives could not be attained without managing urban runoff sources. The call was soon amplified by the 1987 amendments to the federal Clean Water Act and the ensuing regulations promulgated by the U.S. Environmental Protection Agency (USEPA) in 1990 establishing the NPDES stormwater permit program. The first phase of this permit program applied to discharges from municipalities with storm drain systems serving populations of 100,000 or greater and from other state-designated municipal systems connected with the larger municipal systems or determined to be a significant contributor of pollutants to surface waters.

Rather than issuing separate permits to individual local agencies, the Water Board and municipalities agreed that permits covering county-wide areas would be more efficient and manageable. Accordingly, the Water Board issued a permit to all municipalities in Santa Clara County in 1990; similar permits went to Alameda County in 1991, and Contra Costa County and San Mateo County in 1993. Exceptions to this approach were a permit issued to the cities of Fairfield and Suisun City in 1995 and a permit issued to Vallejo in 1998. These permits primarily called for implementation of self-determined management plans covering actions in categorical program areas (described below). These plans were meant to be "living documents," which would be evaluated and revised annually.

More detail was added to the permits when they were reissued in later years, but the management plan approach stayed the same, allowing flexibility and adaptation as municipal efforts evolved and matured. The success of this approach is illustrated by the numerous national and state awards received by Bay Area programs over the past 20 years for efforts to manage stormwater and minimize related adverse impacts on water quality. From the onset of these efforts, the San Francisco Bay Area has been recognized as a national leader in urban stormwater management.

Despite these successes, the Water Board and municipalities began to recognize the potential benefits of a single regional permit. A single permit could address the growing attention to water bodies listed as impaired under Section 303(d) of the Clean Water Act and the resulting total maximum daily loads (TMDLs) and wasteload allocations applicable to storm drain systems, increasing legal and public scrutiny of management plan-based permits, and a desire for more consistency and efficiency. The consolidated MRP has addressed these concerns and raised the effectiveness of stormwater management in the Bay Area to a higher level.

Over the past 20 years, Bay Area stormwater programs have received numerous national and state awards for efforts to manage stormwater and minimize related adverse impacts on water quality

MRP Goals and Overview

The MRP has the following key goals:

- consolidate six separate municipal stormwater NPDES permits into one consistent regional permit;
- include more specificity in the permit language than had been in the previous permits – identifying management actions, the level of implementation, and reporting and effectiveness evaluation requirements – rather than relying on individual municipal stormwater management plans;
- implement and enhance actions to control pollutants of concern, including 303(d)-listed pollutants, consistent with applicable wasteload allocations adopted by the Water Board as part of TMDLs; and
- implement comprehensive and specific monitoring, including incentives to participate in a regional monitoring collaborative.

A fundamental challenge to meeting these goals was for the permit to provide enough flexibility in implementation to account for the different sizes, community characteristics, and resources of the various local agencies, while at the same time ensuring that the MRP remains trackable and enforceable. Thus, a balance between flexibility and enforceability has been crafted into the MRP. Where possible, the MRP prescribes minimum measurable outcomes, while providing local agencies with flexibility in the approaches they choose to achieve the required outcomes.

Like the permits it replaced, the MRP is based on three regulatory drivers:

- a technology-based requirement to reduce pollutants in stormwater discharges to the maximum extent practicable, which roughly translates to implementation of technically and economically feasible control measures;
- a requirement to prohibit non-stormwater discharges to storm drain systems, with certain exemptions; and
- a water quality-based requirement to not cause or contribute to violations of water quality standards for receiving waters.

These drivers are integrated into the MRP framework and its components, including permit provisions for each base program and specific pollutant provision (**Sidebars**).

Each provision of the MRP includes the goal, required actions, minimum implementation levels, and specific reporting elements to substantiate that implementation levels have been met. A number of the historical requirements are enhanced, and new requirements, most notably controls on trash, are included. The MRP also requires comprehensive monitoring to provide a means to measure outcomes and to aid in refining future permits. The following sections provide a summary of the MRP's key provisions.

Base Program Requirements

Municipal Operations

This provision requires appropriate controls to prevent polluted stormwater and non-stormwater discharges to storm drains and watercourses during the operation, inspection, and routine repair and maintenance of municipal infrastructure (streets, roads, storm drains and inlet structures, and municipal facilities). Sediment accumulated on paved surfaces, such as roads, parking lots, parks, sidewalks, and corporation yards, can be a source of pollutants in urban runoff. Road repair, culvert installation, and other rural maintenance activities can disturb the soil and the drainage patterns to streams in undeveloped areas, impacting water quality through excess runoff, erosion, and sediment release.

The most significant enhanced requirement of this provision is to prevent the discharge of water with low dissolved oxygen levels from stormwater pump stations into watercourses. More than 200 pump stations throughout the region are used to overcome the elevation differences between some storm drains and receiving waters (streams or the Bay). Local

Base Program Provisions

Municipal Operations

Industrial and Commercial Site Controls

Construction Site Controls

New Development and Redevelopment

Illicit Discharge Detection and Elimination

Exempted and Conditionally Exempted Non-Stormwater Discharges

Public Information and Outreach

Specific Pollutant Provisions

Pesticides • Trash

Mercury • PCBs • Copper

Polybrominated Diphenyl Ethers (PBDEs), Legacy Pesticides, and Selenium agencies are required to monitor dissolved oxygen at pump stations where water accumulates during dry periods and to take corrective actions if they detect low dissolved oxygen levels, which may cause adverse impacts to receiving waters.

Industrial and Commercial Site Controls

This provision directs municipalities to control discharges to storm drains from industrial and commercial sources through implementation of facility inspection and enforcement programs. Municipalities employ environmental inspectors to conduct stormwater inspections, often in conjunction with other types of inspections such as hazardous materials, pretreatment, and public health (food service facilities). The inspectors use a combination of education and enforcement to eliminate illegal discharges and control potential stormwater pollutant sources, such as outdoor material and waste storage and equipment maintenance and storage.

Several observations can be drawn from annual reports for the past five years from the Alameda, San Mateo, and Santa Clara county programs, which serve more than four million people.

- Nearly 17,000 inspections are conducted, on average, per year.
- Most inspections are conducted at food service and automotive establishments.
- On average, 21% of the inspections result in an enforcement action and resolution, with less than 4% resulting in legal action.

Construction Site Controls

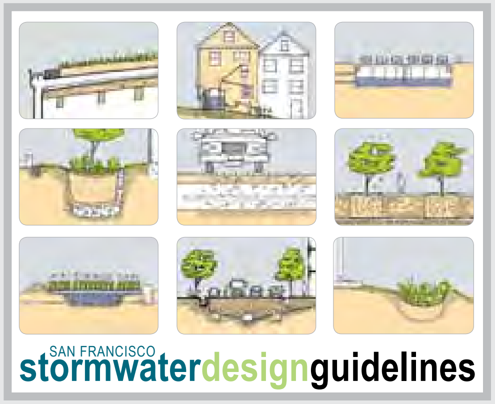
This MRP provision requires construction site inspections and control programs to prevent discharges of pollutants. Clearing vegetation, slope grading, lot leveling, and excavation activities all expose soil to erosion processes and can increase sediment mobilization, runoff, and deposition in receiving waters. Construction materials, equipment, and waste are also potential pollutant sources. Municipalities are required to enforce implementation of erosion controls, run-on and runoff controls, sediment controls, active treatment systems (as necessary), good site management, and non-stormwater management.

New Development and Redevelopment

Under this provision, municipalities must establish and implement requirements for new and redevelopment projects for source control, site design, and stormwater treatment measures, to prevent and control pollutant discharges, and to limit increases in runoff flows. Previous permits included requirements to regulate stormwater quality at projects creating and/or replacing 10,000 square feet or more of impervious area. The MRP reduces the impervious area threshold to 5,000 square feet for auto service facilities, retail gas outlets, restaurants, and uncovered parking. The MRP also retains previous permit requirements to regulate hydromodification (the change in the runoff characteristics) at projects creating or replacing one acre or more of impervious surface to prevent an increase in erosion to receiving waters. Runoff flow and volume cannot exceed pre-project rates and durations where increased flow or volume is likely to heighten erosion of creek beds and banks and silt generation.

The MRP includes a new requirement to implement low-impact development (LID) measures. The goal of LID is to reduce runoff and mimic a site's predevelopment hydrology by minimizing disturbed areas and impervious cover; under these more natural conditions, stormwater runoff infiltrates, is stored and detained, evapotranspires, or is biotreated at its source. LID employs principles such as preserving open spaces and natural features of the project site, minimizing hardscape, capturing runoff for use onsite, and using permeable surfaces and landscaping. LID tools include rain barrels and cisterns, green roofs, permeable pavement, rain gardens, and planters and tree boxes. By utilizing self-renewing biological processes, landscaped-based LID practices provide effective and dependable stormwater treatment and flow reduction, as well as low maintenance costs.

Although the LID permit requirements are new, most Bay Area municipalities have been implementing LID concepts since the mid-1990s. The Bay Area Stormwater Management Agencies Association (BASMAA) guide, Start at the Source Design Guidance Manual for Stormwater Quality Protection, was published in 1996 and was updated and expanded in 1999. It is still used as a resource by California municipalities preparing their own LID guidance manuals. In response to previous permits, Bay Area municipalities reviewed their local ordinances, policies, and design standards and made revisions to facilitate the use of LID practices and compliance with the requirements. Some municipalities – notably Milpitas, Emeryville, and Contra Costa County and its 19 cities and towns – issued their own specific guidance and requirements for LID treatment.



Most Bay Area municipalities have been implementing low impact development concepts since the mid-1990s. As one example of these efforts, in 2009 the San Francisco Public Utilities Commission and the Port of San Francisco published a report – San Francisco Stormwater Design Guidelines – to help San Francisco's developers, designers, engineers, and the general public implement stormwater controls for new and redevelopment projects. The guidelines cover many different types of development scenarios. Measures that can be used to control stormwater runoff from high-density residential areas are shown in this illustration. In these areas, the greatest opportunities for stormwater management reside in replacing impervious surfaces with pervious surfaces and adding green space to roofs and interior courtyards. Ample roof space with relatively low pollutant loads provides opportunities for eco-roofs and rainwater harvesting. Interior courtyards can accommodate landscape-based best management practices (BMPs), permeable paving, and subsurface treatment or capture systems. Sidewalks and streets adjacent to high-density residential development are often the nearest public open spaces available to residents. As such, they are ideal places to site stormwater management BMPs that also improve streetscape aesthetics and provide wildlife habitat, such as biofiltration areas, street trees, green walls, and bioretention bulbouts. All of these measures help to manage stormwater runoff; they also reduce the volumes of stormwater generated by the site in the first place.

1 Downspout Discharges to Vegetated Roof to Reduce Runoff

2 Vegetated Roof to Reduce Runoff

3 Green Wall to Slow Runoff

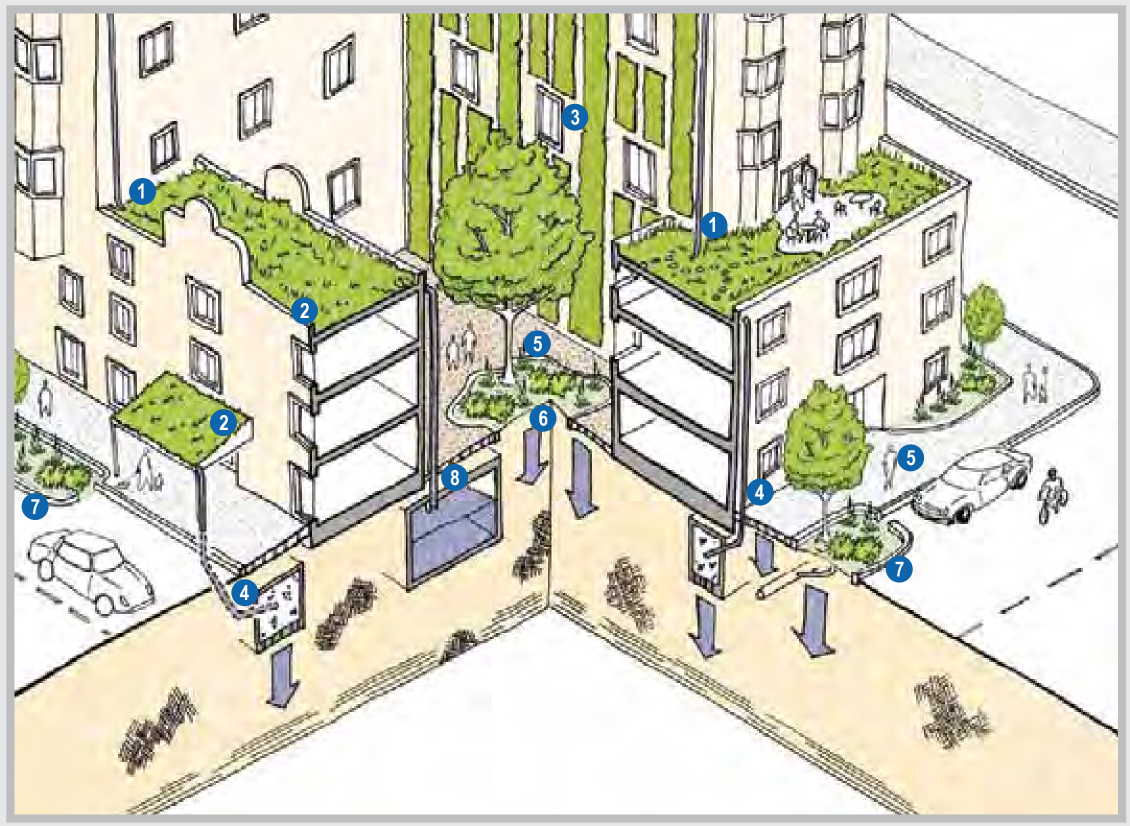
4 Downspout Connected to Dry Well

5 Permeable Paving in Pedestrian Areas

6 Rain Garden for Bio-Infiltration

7 Bioretention Planter with Curb Cuts

8 Downspout Connected to Large-Scale Cistern for Rainwater Harvesting



Footnote: Courtesy of the Urban Watershed Management Program, San Francisco Public Utilities Commission.

Reference: SFPUC and Port of San Francisco. 2009. San Francisco Stormwater Design Guidelines. http://www.stormwater.sfwater.org

DALY CITY LIBRARY RAIN GARDEN: AN EXAMPLE OF LOW IMPACT DEVELOPMENT (LID)

A promising option for stormwater treatment at the source using LID treatment measures was evaluated at a Daly City library parking lot during the 2009/10 wet season. Four rain gardens (bioretention areas) and one bioswale were installed to treat runoff from the parking lot, as well as tennis and basketball courts and a popular community area with an average of over 20,000 visitors per month. The rain gardens and bioswale, with a total surface area of approximately 4% of the entire four-acre runoff area, effectively trapped contaminants during the first year after installation.

Monitoring prior to rain garden installation showed contaminant concentrations in runoff that were between five (total mercury) and 88 times (PAH) higher than the average concentrations in Central San Francisco Bay. During 2009/10, considered to be a wet year, runoff from most storms (88%) was successfully filtered through the rain gardens and bioswale before it was discharged into a tributary of Colma Creek. Preliminary results suggest that contaminant loads were reduced between 50% and 80% for mercury, copper, cadmium, nickel, lead, zinc, PCBs, and PAHs when water was captured by the LID treatment measures. Twelve percent of the storms exceeded the capacity of the rain gardens and bioswale and were bypassed into the storm drain to avoid flooding. Under the MRP, many new development and redevelopment projects will include this kind of stormwater treatment that not only improves the aesthetic value of the area but will also meet MRP treatment requirements.

LEFT and RIGHT →
Rain gardens at the
Daly City library site.
Photographs by Nicole David.

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PUBLIC PARTICIPATION: WATERSHED GROUPS IN THE BAY AREA

The San Francisco Bay Area is rich in citizen involvement and watershed groups, with over 100 creek and watershed groups around the nine-county Bay Area, ranging from large watershed councils developing comprehensive watershed plans to regional watershed forums to both well-established and fledgling "friends of" creek groups doing hands-on creek cleanup, restoration, and native plant revegetation. These many groups are a significant resource for communities, agencies, and other stakeholders, as they provide local knowledge, community outreach and engagement, practical experience, and scientific monitoring data to protect and restore critical Bay Area habitats and native species. Some watershed groups are completely citizen-organized, while other groups have been sponsored and supported by organizations such as Resource Conservation Districts, local and regional non-profits, municipal stormwater programs, and water districts.

A number of Bay Area watershed groups are doing volunteer-based monitoring to assess the health of creeks and other waterways. For example, the Contra Costa Watershed Forum, supported by Contra Costa County, has worked with community groups, the Department of Conservation and Development, and the Contra Costa Clean Water Program to implement a creek monitoring program that partners with volunteers to study creeks, using GPS mapping technology and benthic community (sediment-dwelling animals) assessment. In the South Bay, volunteers with the Stevens and Permanente Creeks Watershed Council have an ongoing water quality monitoring program, in collaboration with De Anza College, as well as a benthic community study, GPS plant mapping, and riparian revegetation projects.

A recent watershed-focused effort is the formation of the Bay Area Watershed Network (BAWN), formed in late 2006 to bring together a wide variety of watershed stakeholders, including restoration practitioners, scientists, resource agencies, non-profits, and flood control districts. A major goal for BAWN is to share expertise and information and create a more cohesive regional watershed community, by giving a voice to on-the-ground efforts in the context of the entire San Francisco Bay watershed. One of the BAWN working groups is focused on monitoring, assessment, and restoration tools and is working on developing a matrix of tools and an outline for urban and rural restoration objectives. As we face the many challenges of the 21st century, watershed groups will increasingly be a major force in environmental protection in the Bay Area.

GPS mapping of vegetation at McLellan Ranch Park in Cupertino. Photograph by Joanne McFarlin.

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Illicit Discharge Detection and Elimination

This provision requires implementation of an illicit discharge prohibition and measures that ensure that illicit discharges are detected and controlled in areas not otherwise addressed through the municipal operations, industrial and commercial site control, and construction site control program areas. Municipalities are required to perform active surveillance of key locations in the storm drain system and to maintain centralized complaint collection to detect illicit discharges and take steps to eliminate them.

Local agencies typically detect, respond to, and resolve thousands of illegal discharge incidents each year. Typical incidents tend to be associated with washwaters, sanitary spills, construction-related discharges, and waterline breaks. Roughly 40% of these incidents require enforcement; the remaining 60% are resolved through verbal warnings and education by local agency responders.

Exempted and Conditionally Exempted Non-Stormwater Discharges

The MRP prohibits non-stormwater discharges into the storm drain system unless authorized by another NPDES permit. In addition, the MRP provides exemptions for unpolluted non-stormwater discharges and discharges with appropriate controls. This provision identifies the exempted discharges (e.g., uncontaminated flows from natural springs) and conditionally exempted discharges. Examples of the latter include potable water system discharges that are dechlorinated and swimming pool and fountain discharges that do not contain algaecides and are dechlorinated.

Public Information and Outreach

The goal of this provision is to increase public awareness and promote appropriate solutions, such as proper waste disposal, to change behaviors and practices that contribute to stormwater pollution. Municipalities must foster watershed stewardship by providing opportunities for direct public involvement in preventing stormwater pollution and encouraging activities that are beneficial to the watershed. The MRP requires that municipalities continue and enhance existing efforts such as storm drain inlet marking, advertising campaigns, outreach and citizen participation events, and focused outreach to school-age children. Many of these efforts in the Bay Area have won state and national recognition; these campaigns have made residents aware of storm drain systems and their personal responsibilities, including how personal choices have an adverse or beneficial impact on water quality.

Websites for the municipal stormwater programs provide access to information and opportunities for public participation, including Alameda Countywide Clean Water Program (www.cleanwaterprogram.org), Contra Costa Clean Water Program (www.cccleanwater.org), San Mateo Countywide Water Pollution Prevention Program (www.flowstobay.org), and Santa Clara Valley Urban Runoff Pollution Prevention Program (www.mywatershedwatch.org).

Requirements for Specific Pollutants

The MRP does not contain numerical limits for pollutants, but rather narrative limitations for specific pollutants. These limits are based on updated determinations of pollutants that may be impairing water quality and updated information on approaches to reduce specific pollutants to the maximum extent practicable. The MRP also requires evaluations of promising new or enhanced controls that have yet to be adequately tested, in order to inform the next iteration of the Permit.

Pesticides

This provision implements requirements of the TMDL for diazinon and pesticide-related toxicity in urban creeks in the Bay Area. To prevent the impairment of urban streams by pesticide-related toxicity, municipalities are required to implement a pesticide toxicity control program that addresses use of pesticides that pose a threat to water quality and that have the potential to enter stormwater conveyance systems.

Concerns over diazinon-related toxicity in urban creeks, which were significant in the 1990s, have diminished since the U.S. Environmental Protection Agency eliminated urban uses in 2004. However, replacement pesticides, particularly pyrethroids (e.g., bifenthrin, cyfluthrin, beta-cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, lambda-cyhalothrin, permethrin, and tralomethrin), are now found in urban creeks, often at toxic levels. Carbamates (e.g., carbaryl) and fipronil are other pesticides of concern.

The requirements of this provision are consistent with previous permits and reflect ongoing efforts by many municipalities to control their own use of these pesticides and to reduce the use of pesticides by the public and other entities. Federal and state law constrains municipal authority to regulate pesticide use, which means local governments can control their own use, but not uses by other parties.

Accordingly, the MRP requires municipalities to control their own use by establishing and implementing an Integrated Pest Management (IPM) policy or ordinance for municipal pest control and to ensure that municipal employees and contractors who use pesticides implement IPM.

To influence the use of pesticides by the public and other entities, municipalities must provide targeted information on proper pesticide use and disposal, potential adverse impacts on water quality, and less toxic methods of pest prevention and control. The Our Water, Our World program, begun by Bay Area local agencies in 1997, is a very successful point-of-purchase campaign (at hardware stores and nurseries) and web-based (www.ourwaterourworld.org) outreach effort to assist consumers in managing home and garden pests in a way that helps protect water quality. The MRP also requires outreach to professional pest control operators to promote the use of IPM and to support IPM-certified contractors. It also calls on municipalities to track and participate in USEPA's and the California Department of Pesticide Regulation's efforts to review and evaluate use and permitting of pesticides of concern, such as recent and ongoing attention to pyrethroids.

Trash

The most extensive new requirements in the MRP address a continuing water quality and societal issue: trash and litter along Bay Area creeks and shorelines. The trash reduction requirements are multifaceted and focus both on short-term actions to remove trash from known creek and shoreline hot spots and long-term actions to significantly reduce trash discharged from municipal storm drain systems. During this permit term, municipalities are required to develop and implement a Short-Term Trash Load Reduction Plan to attain a 40% reduction of trash loads by 2014. Municipalities are then required to use their short-term experiences and lessons learned to develop and begin implementation of a Long-Term Trash Load Reduction Plan, to attain a 70% reduction in trash loads by 2017 and 100% by 2022.

> The MRP requires municipalities to reduce trash loads 40% by 2014, 70% by 2017, and 100% by 2022

Required short-term actions include implementation of a mandatory minimum level of trash capture, cleanup, and abatement progress on a mandatory minimum number of trash hot spots, and development of a trash baseline load and load-reduction tracking method. Municipalities are required to install and maintain full trash capture devices to treat runoff from an area equivalent to 30% of land used for retail and wholesale businesses (over 5,700 acres region-wide). This effort has been facilitated by a recent federal $5 million American Recovery and Reinvestment Act grant to the San Francisco Estuary Partnership to fund installation of trash capture devices. Municipalities are also required to conduct annual cleanup and assessment (quantity and type of trash) of over 350 designated trash hot spots in creeks and along shorelines throughout the region. The MRP also requires development of a standard method to quantify trash loading from storm drain systems; no such method presently exists, and it would be useful for tracking and informing trash load reduction actions.

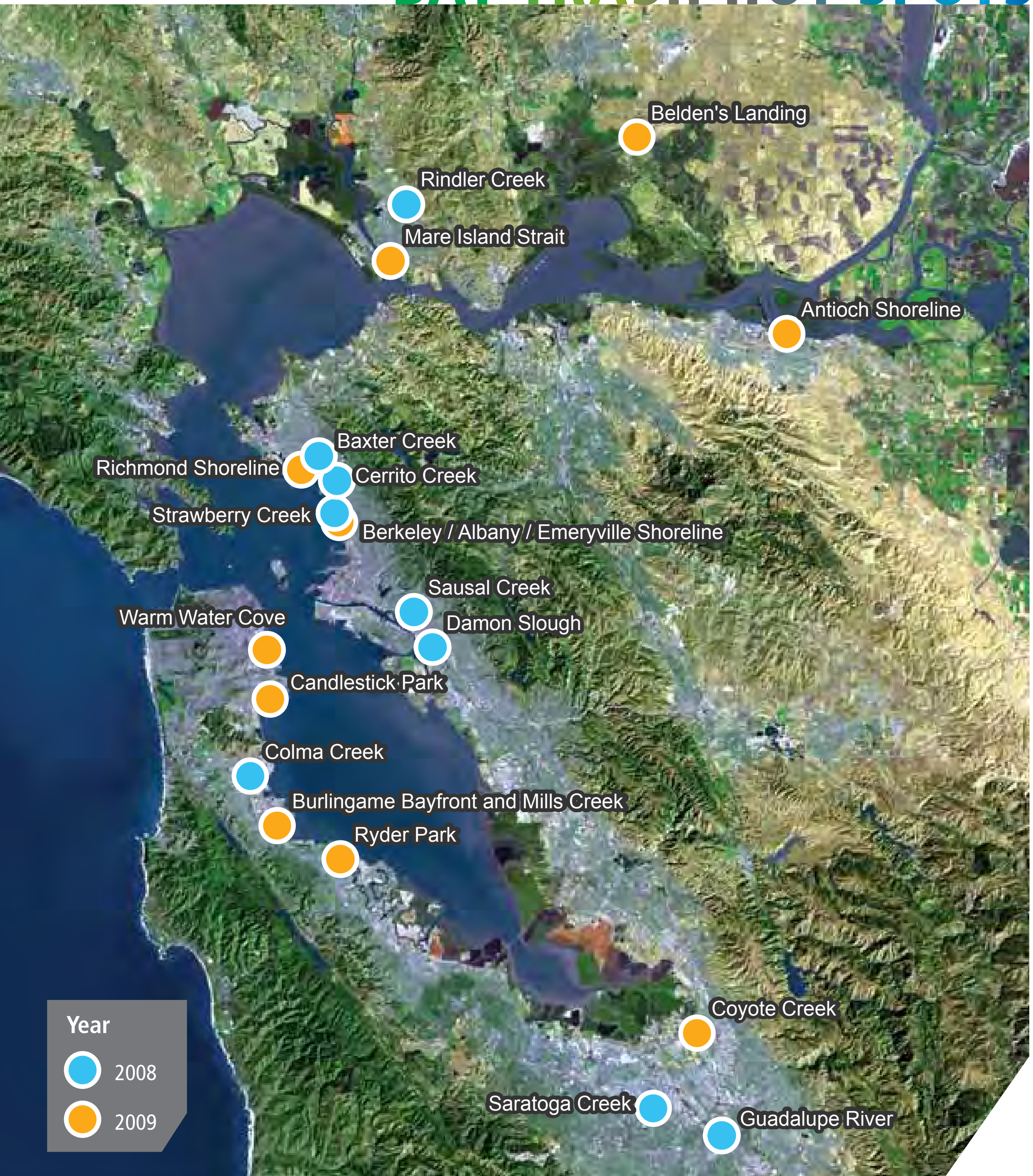
Mercury and PCBs

The provisions for mercury and PCBs in the MRP are consistent with the regulatory approaches and implementation plans of the San Francisco Bay mercury and PCBs TMDLs adopted by the Water Board. These requirements seek to build the understanding and level of certainty concerning control of these pollutants.

With a few exceptions, municipalities have limited experience with implementation of mercury and PCB controls. Accordingly, the MRP requires pilot-testing various controls in selected locations. Many of the controls addressing mercury and PCBs will likely result in reductions of a host of sediment-bound pollutants, including legacy pesticides and polybrominated diphenyl ether (PBDE) flame retardants. The removal of multiple pollutants will be a key factor in the consideration and evaluation of control methods. The current strategy is to base decisions concerning where to focus effort on the distribution of PCBs, but evaluation of the effectiveness of controls will take other pollutants into account. The results will inform future MRP requirements to continue, expand, or cease implementation of specific requirements.

Both the mercury and PCB provisions require pilot projects to evaluate various controls and control strategies. Municipalities are directed to conduct reconnaissance surveys to identify sources in five drainage areas in the region that have relatively high levels of PCBs (and likely mercury) in storm drain sediments. Municipalities must then either use their own authorities or refer sites to regulatory agencies for cleanup and abatement.

BAY TRASH HOT SPOTS



Since 2006, Save The Bay (www.savesfbay.org) has published an annual list of Bay Trash Hot Spots to identify areas blighted by trash and to raise awareness about this problem.

In 2008 the hot spots included 23 trash-polluted waterways draining directly to San Francisco Bay. Using monitoring data and photo evidence collected by the Water Board, Save The Bay members, and concerned citizens, the Water Board listed the sites as "trash-impaired waterways." This designation triggered formal steps to significantly reduce trash in the Bay through regulation.

Save The Bay's 2009 list underscored the pervasive and growing problem of plastic trash in our waterways. The 2009 hot spots were ten Bay shoreline and creek locations where volunteers removed the most plastic bags on Coastal Cleanup Day in September 2008. On this day alone, volunteers picked up nearly 15,000 plastic bags from these locations – a shocking number given that only a small portion of the Bay shoreline and its tributaries were cleaned up. Save The Bay estimates that more than one million plastic bags wind up in the Bay each year. Plastic bags smother wetland habitat and degrade water quality. Animals are often killed when they mistake bags for food or become entangled in them. Plastic bags and other plastic products break up into tiny pieces that remain in waterways for decades or centuries.

The 2010 list will be revealed on September 21, 2010 (after this edition of *The Pulse* is in press) on Save The Bay's website: www.savesfbay.org/baytrash. In this round the community will have the chance to vote on a site that Save The Bay will adopt and clean up regularly throughout the year, with the help of volunteers.

Implementation of the Trash Load Reduction Plans in the Municipal Regional Stormwater Permit promises to contribute to a substantial reduction in the amount of trash in creeks and along the Bay shoreline.

For more information contact Jessica Castelli at Save The Bay at 510-452-9261 x104 or visit www.savesfbay.org.

Background image courtesy of USGS.

In addition, municipalities are required to pilot-test controls in the five drainage areas to enhance removal of sediment with PCBs, mercury, and other pollutants during existing municipal operation and maintenance activities, such as inlet or storm drain cleaning and street flushing and capture, collection, or routing to the sanitary sewer of the water used. Municipalities also must collaboratively pilot-test 10 urban runoff treatment retrofits of various types, such as biotreatment units or sand filters, and to pilot-test diverting dry-weather or first-flush flows from five stormwater pump stations to the sanitary sewer for treatment by local municipal wastewater treatment plants. The financial burden to implement these various pilot projects has been eased in part by a recent $5 million grant to the BASMAA from USEPA's San Francisco Bay Water Quality Improvement Fund.

Other pilot projects specific to both mercury and PCBs are required under the MRP. A PCB project will evaluate the presence of PCBs in building materials (e.g., caulks) and develop controls to prevent such building materials from being released to the environment during demolition or renovation projects. An additional PCB-specific requirement is to incorporate identification of PCBs and PCB-containing equipment into industrial inspections. A mercury-specific requirement calls for maintaining programs to collect and recycle consumer products containing mercury.

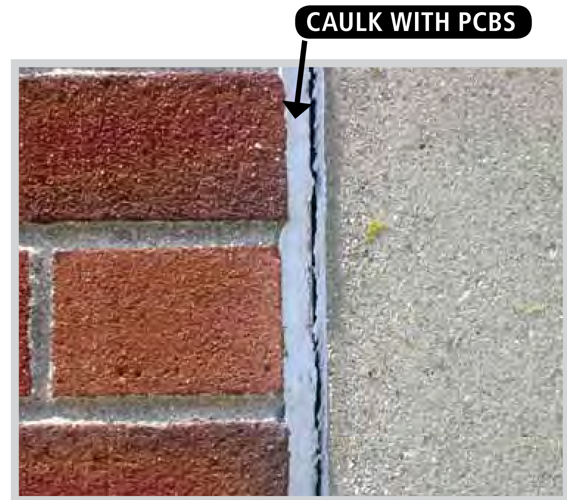
The mercury and PCB provisions also include requirements to study the fate and transport of these contaminants in urban runoff to inform review and potential revisions of the TMDLs. Another obligation is participation in a regional risk reduction program that will educate appropriate communities about the health risks of consuming Bay fish with relatively high levels of mercury and PCBs.

Copper

Copper control requirements are associated with the site-specific water quality objectives for dissolved copper that were recently established by the Water Board for all segments of the Bay. To maintain water quality in the Bay, municipalities are required to implement actions to control discharges to storm drains from architectural (e.g., roofs) and industrial (e.g., metal plating) uses of copper, as well as copper used as an algaecide in pools, spas, and fountains. They are also required to address vehicle brake pads, which are the largest source of copper to the Bay, through ongoing participation in the Brake Pad Partnership, a public-private collaborative formed to evaluate this issue.

Polybrominated Diphenyl Ethers (PBDEs), Legacy Pesticides, and Selenium

The goal of this provision is to gather information on the magnitude and extent of PBDEs, the legacy organochlorine pesticides (DDT, dieldrin, and chlordane), and selenium in urban runoff. Most Bay segments are on the state's 303(d) List of impaired water bodies for the legacy pesticides and selenium, and PBDEs are an emerging concern. MRP requirements include collecting data to characterize the distribution of PBDEs, legacy pesticides, and selenium in urban runoff and identifying existing and potential controls, building where possible on mercury and PCB control efforts. These actions will inform review of impaired waters listings, development of TMDLs, and future permit requirements.



↑ TOP PHOTOGRAPH:
A PCB project in the MRP will evaluate the presence of and develop controls for PCBs in building materials, such as caulks. Photographs from www.pcbsinschools.org.

↑ BOTTOM PHOTOGRAPH:
The Brake Pad Partnership (http://www.suscon.org/bpp/index.php) is addressing vehicle brake pads – the largest source of copper to the Bay.

Water Quality Monitoring

Water quality monitoring requirements in the individual permits were general and focused on answering broad questions about sources of pollutants, effectiveness of controls, and effects on the receiving water. Using results of monitoring conducted by the municipal stormwater programs and the Water Board's Surface Water Ambient Monitoring Program (page 68), more prescriptive and expansive management questions have been developed to guide monitoring requirements in the MRP. The MRP requires several types of monitoring activities.

- San Francisco Bay Estuary Monitoring – Monitoring of the Bay through participation in the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) or equivalent.
- Urban Creek Status Monitoring – Monitoring to assess water quality and the condition of beneficial uses in the urban portions of local creeks and rivers.
- Monitoring Projects – Stressor and source identification projects triggered by the results of urban creek status monitoring; investigations of stormwater treatment control effectiveness; and geomorphic projects to assess how creeks can be restored or protected to cost-effectively reduce the adverse impacts of pollutants, increased flow rates, and increased flow durations of urban runoff.
- Pollutants of Concern and Long-Term Trends Monitoring – Evaluation of inputs of pollutants to the Bay from local tributaries and urban runoff, assessment of progress toward achieving TMDL wasteload allocations, and working to reduce uncertainties associated with loading estimates of pollutants to the Bay.
- Citizen Monitoring and Participation – Encouragement of citizen monitoring and incorporation of monitoring data collected by citizens into water quality assessments.

A regional monitoring coalition is expected to provide an efficient, consistent, and cost-effective means of monitoring

Many of these monitoring activities will be coordinated through a regional monitoring coalition. The coalition is expected to provide an efficient, consistent, and cost-effective means of monitoring creeks that will be coordinated with the Water Board's Surface Water Ambient Monitoring Program and the RMP's Small Tributary Loading Strategy (page 30). Additional benefits will include coordinated information management, access, and reporting.

Challenges

The MRP is focused on a number of priority areas, such as consistent implementation of base program controls; enhancement of new and redevelopment controls through further implementation of LID practices; implementation of controls consistent with currently adopted pesticide, mercury, and PCB TMDLs; focused efforts to address trash; and expanded monitoring with a link to relevant management questions. However, while these requirements are the local stormwater agencies' highest priorities, finding cost-effective means to implement them will be very difficult during the current economic downturn.

While the MRP provisions are well-aimed to improve water quality, the requirements will place a considerable strain on public agency resources, particularly given aging storm drain infrastructure needs that also must be addressed. Thus, it is paramount that state and local agencies continue to work together effectively, where practicable, to identify unintended consequences, establish and evaluate implementation priorities during the course of the current and future MRPs , and continually secure state and federal grant resources to assist with local implementation.

The Water Board and stormwater management agencies will meet these challenges as they continue their efforts to protect and enhance water quality in the Bay and its tributaries.

PROMISING FINDINGS FROM A STUDY OF URBAN STORMWATER MANAGEMENT OPTIONS

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Highlights

- With funding from the State Water Resources Control Board, Bay Area scientists and managers partnered in an initial study of management options for PCBs and mercury in urban stormwater
- PCB and mercury are unevenly distributed in the urban environment, suggesting that management actions should focus on more contaminated sites where benefits will be largest and most easily measured
- Initial evaluation of best management practice (BMP) scenarios indicated that mercury may be best addressed through source control and maintenance, such as local air emissions control, mercury recycling, street sweeping, and drop inlet cleaning
- For PCBs, the most promising BMP scenarios included capture during building demolition, and treatment of high concentration soils and runoff from industrial areas
- Information from this study has been organized into a series of fact sheets targeted for stormwater managers

↖ Sampling sediment from a storm drain in Emeryville. Photograph by Alicia Gilbreath.

A Partnership to Reduce Loads from Stormwater

Mercury and polychlorinated biphenyls (PCBs) are pollutants of concern in San Francisco Bay due to their persistence in the environment and their potential to adversely impact humans and wildlife. Both are considered "legacy" pollutants because their use has declined due to production bans, use restrictions, and product substitutions, but they persist in the environment and continue to bioaccumulate in the food web. Spills, improper disposal, and ongoing uses still result in releases to the Bay. Mercury use in processes and products has been greatly reduced since the peak in domestic demand in the late 1960s, but continued presence in some products and global releases, from activities such as coal burning, prolong impacts in the Bay. New PCB uses have been banned since the late 1970s, but PCB-containing equipment such as electrical transformers remain in service.

Knowledge about the distributions and effects of these pollutants in the Bay has grown greatly since a fish consumption advisory was first issued in 1994. For over a decade, the San Francisco Bay Regional Water Quality Control Board (Water Board) has worked on these problems and has mapped out plans for recovery through the development of Total Maximum Daily Loads (TMDLs) for mercury and PCBs (SFBRWQCB 2006, 2008). The TMDL reports compare pollutant loads entering the Bay from various pathways, describe the processes by which these pollutant loads travel and lead to negative impacts on beneficial uses, and propose load reductions for the various pathways. The TMDLs call for greatly reduced urban stormwater loads, approximately 50% for mercury and 90% for PCBs, within 20 years.

Conceptually, two approaches could achieve mercury and PCBs load reductions in urban stormwater. One approach would reduce loads across the entire region, an inefficient strategy that may be impossible to implement. In areas that already have low concentrations, further reductions would be difficult. The other approach would focus on "high leverage" areas known to have higher concentrations and loads. Once high leverage areas are identified, this approach would be more efficient; the challenge, however, is in locating these areas.

To learn more about the potential for available types of control measures to assist in reducing loads of mercury, PCBs, and possibly other pollutants, the State Water Resources Control Board (State Water Board) funded the Regional Stormwater Monitoring and Urban Best Management Practice (BMP) Evaluation: A Stakeholder-Driven Partnership to Reduce Contaminant Loadings (generally called the Regional BMP Evaluation).

The project included a number of significant supporting components, including a field study of PCB and mercury concentrations in soils and sediments in industrial areas; a lab study of pollutant partitioning by particle size; a summary of the potential application and effectiveness of BMP scenarios, using a simple spreadsheet model; and a synthesis called A BMP Toolbox for Reducing PCBs and Mercury in Municipal Stormwater. **FIGURE 1** presents a schematic summary of the potential intervention points considered. These and other products are accessible at http://www.sfei.org/urbanstormwaterBMPS.

An efficient approach to reduce contaminants in urban stormwater would focus on "high leverage" areas that have higher concentrations and loads

Searching for the Most Contaminated Soils and Sediments

The field study of PCB and mercury concentrations in soils and sediments in industrial areas was designed to identify and rank areas for further study and provide information for evaluating the design and effectiveness of potential control measures.

In previous studies of PCB and mercury distributions, the Bay Area Stormwater Management Agencies Association (BASMAA) sampled sediments in urban stormwater conveyances in 2000 and 2001 (KLI 2001; KLI 2002; Salop et al. 2002a). During those surveys, a number of locations with elevated concentrations of PCBs and mercury were found, primarily in industrial and commercial areas. This finding led to followup surveys that focused on industrial and commercial sites (e.g., Salop et al. 2002b; STOPPP 2002; San Jose and EOA 2003; STOPPP 2003; STOPPP 2004; Kleinfelder 2005; Kleinfelder 2006; EOA 2007). In many cases, subsequent sampling found lower concentrations than had been detected in the earlier studies, in some

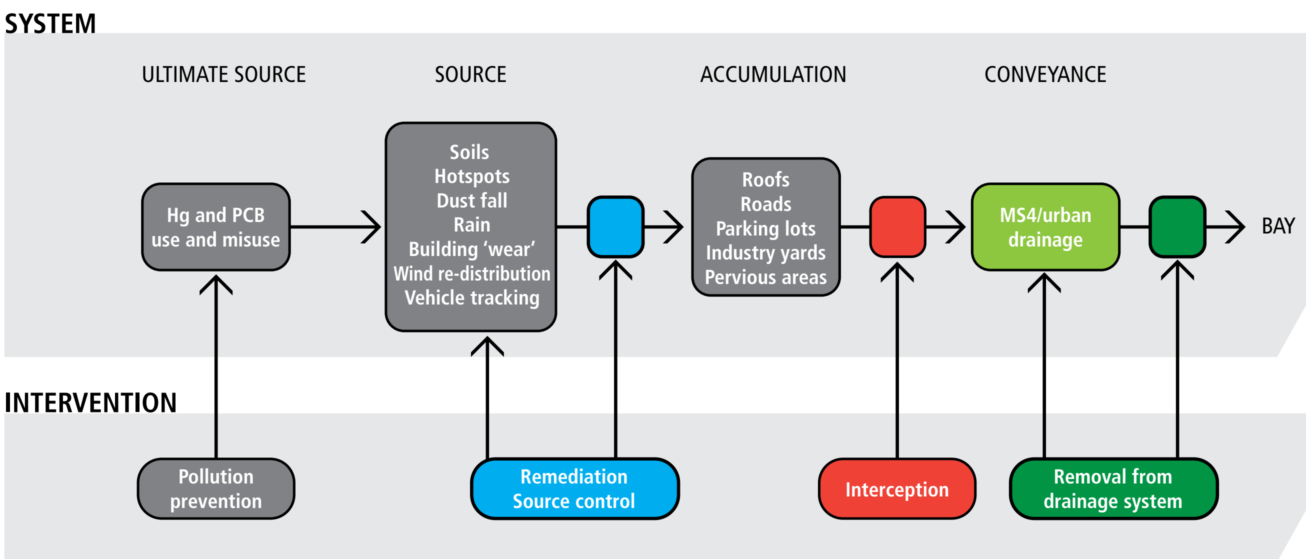


FIGURE 1
The study evaluated BMP options within the context of a conceptual model for the source-to-Bay transport of pollutants. Some control practices address product usage, disposal, and recycling (pollution prevention), some address the accumulation of pollutants on impervious source areas (source control), and some address removal of pollutants from the drainage network (treatment BMPs and maintenance practices).

cases below thresholds of concern. Even where high concentrations were confirmed, followup studies were often unable to identify the sources of elevated concentrations.

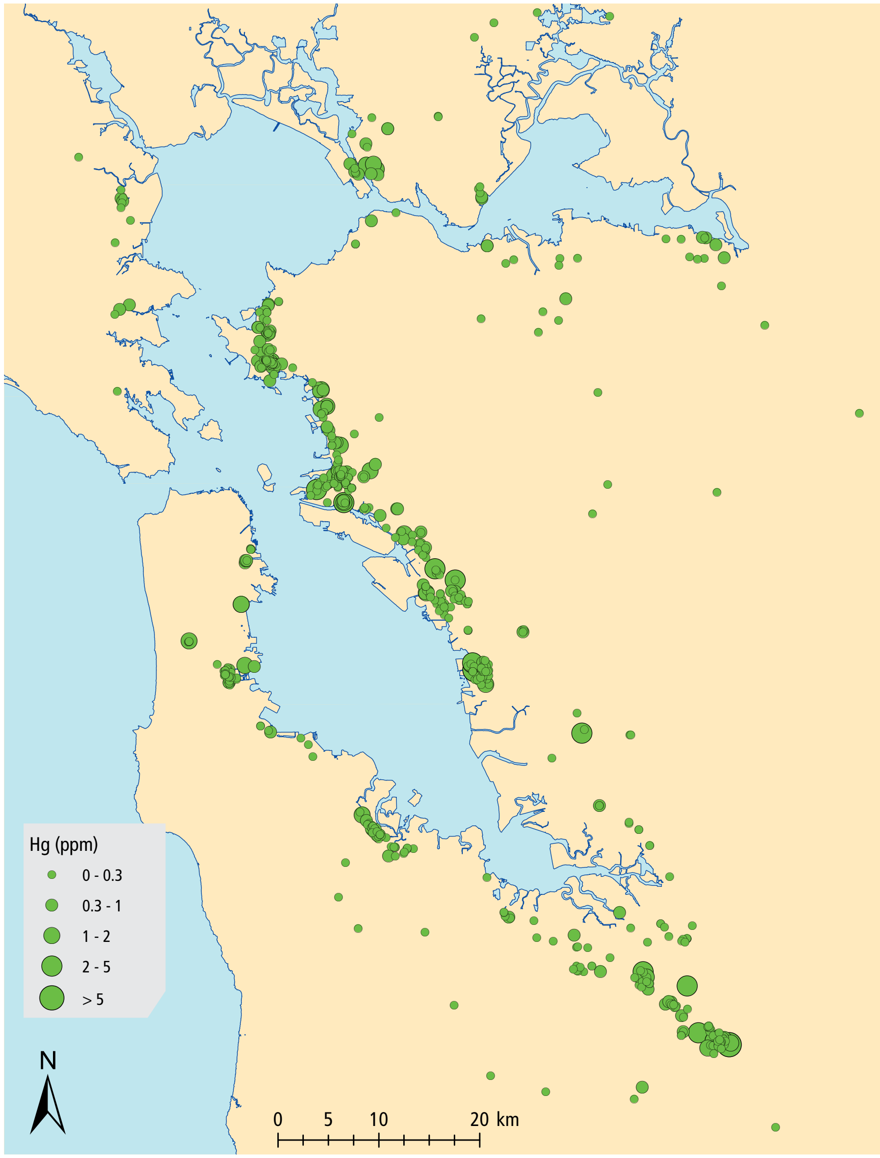
The Regional BMP Evaluation added to the local data set, sampling sediment from street gutters and storm drain inlets at more than 360 additional locations, primarily in industrial and commercial areas. These data, combined with those from previous studies (FIGURES 2 AND 3), were analyzed to evaluate similarities in urban sediment and soil contamination of nearby sites, compare mercury and PCB concentrations in contaminated areas, and rank the most contaminated patches based on all the available data.

Analysis of 650 data points from the Bay Area showed general similarities in pollutant concentrations for sites within 3 km of one another. This relationship held true for both mercury and PCBs, suggesting that general land use character and transport mechanisms may be important. The similarities are visible in FIGURES 2 and 3 as overlapping medium and large circles representing moderate and very high pollutant concentrations.

Within industrial and commercial areas with generally elevated concentrations, the mercury and PCB concentrations varied widely. This variability, seen in the maps as small dots within and adjacent to medium and larger circles, reflects the episodic nature of release and transport of the pollutants from some sources. For example, concentrations in soils could be very high at a spill site but at low background concentrations only a few tens of meters away.

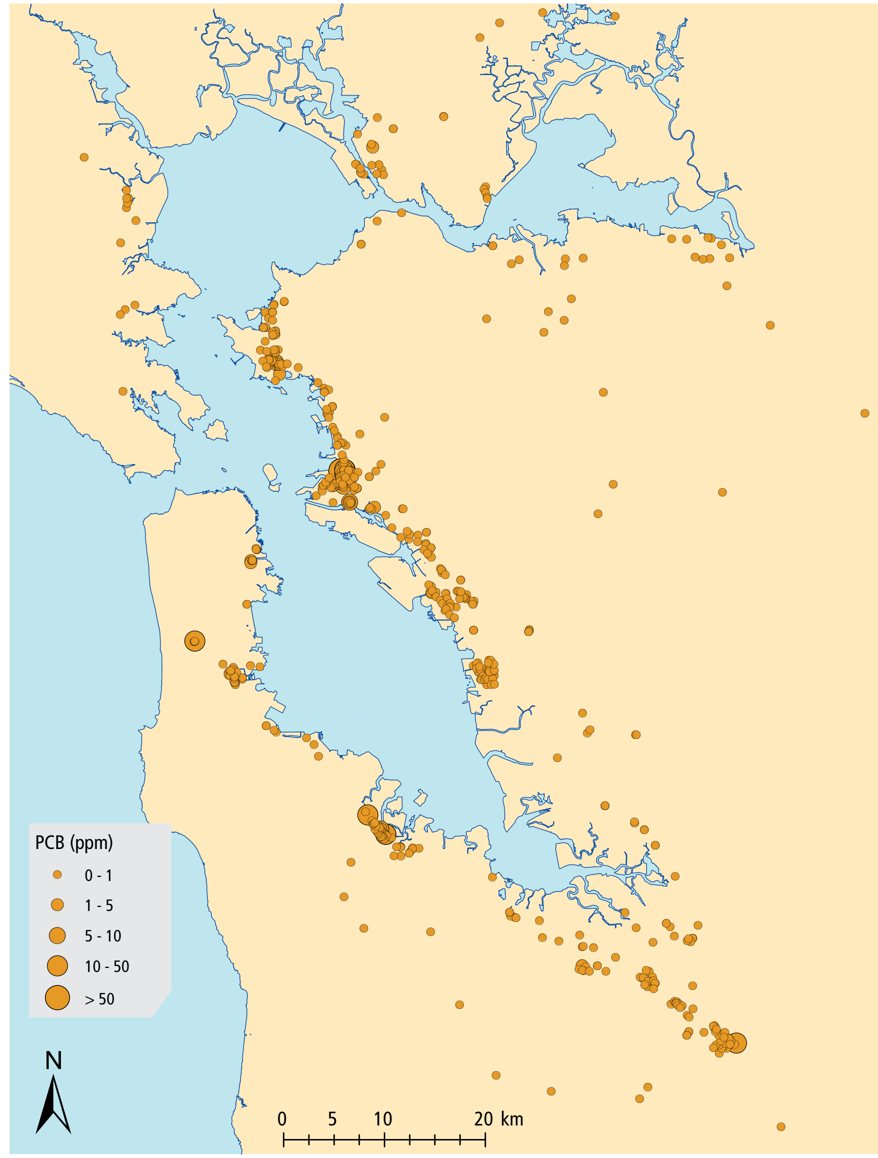
Since few products and processes require both PCBs and mercury, it was not surprising that the individual sites most contaminated with PCBs were not the same sites that were contaminated with mercury. PCBs were dominantly used in electrical applications with smaller amounts being used in hydraulic fluids, lubricants, and plasticizers. Mercury was used in batteries, paint, lighting, pressure and temperature sensing devices, and switches.

These results fit the expectations for mercury and PCB distributions, but present challenges for implementation of BMPs to meet load reduction goals. The largest challenge is that the best areas to control PCBs will likely be different from those for mercury, although there are some locations with moderately high concentrations of both where controls to address both can be tested. Reducing attention to open space and residential areas can help focus the application of the limited resources of stormwater agencies, but industrial and commercial areas represent a sizeable portion of the total watershed, so uniform application of the same control methods to all such areas may not be the most effective or efficient use of resources. Most contaminated sites are in industrial and commercial areas, but



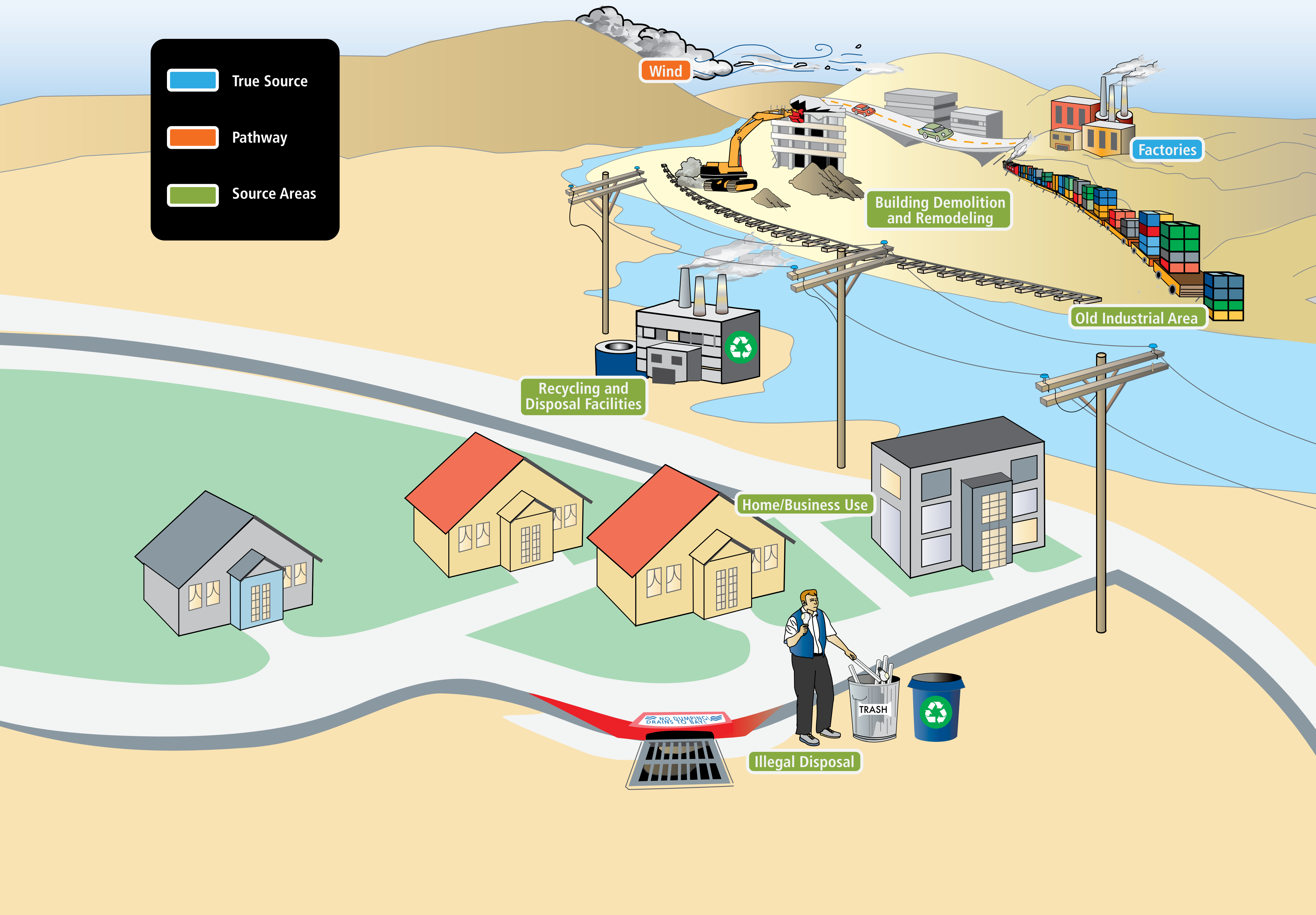
↑ FIGURE 2

Mercury concentrations on sediment particles in stormwater collection facilities, street gutters, and storm drain inlets are highly patchy, even within industrial and commercial areas with generally elevated concentrations. This patchiness, seen as small dots within and adjacent to medium and larger circles, reflects the episodic nature of many release and transport processes.



↑ FIGURE 3

PCB concentrations on sediment particles in stormwater collection facilities, street gutters, and storm drain inlets are also very patchy. Individual sites and areas most contaminated with PCBs are often not the same as those with high mercury, posing a challenge for meeting load reduction goals for both pollutants.


True Source
Pathway
Source Areas
Wind
Factories
Building Demolition and Remodeling
Old Industrial Area
Recycling and Disposal Facilities
Home/Business Use
TRASH
NO DUMPING! DRAINS TO BAY!
Illegal Disposal

Contaminants in urban runoff can be traced back to a myriad of places and activities in the urban landscape. In considering these origins, the BMP evaluation project distinguished three general categories: true sources, source areas, and transport pathways. True sources are the original points of introduction of contaminants into the urban landscape. True sources of mercury and PCBs include historic mines, factories, and atmospheric deposition. Source areas are places in the landscape where contaminants were used, inadvertently released, systematically discarded, or accumulated. Sources areas for mercury and PCBs include old industrial areas, other areas where PCBs are still in use, recycling facilities, road deposits, homes and businesses, areas with illegal disposal, and building demolition or remodeling. Transport pathways are conduits or processes that deliver contaminants from the true source or source area to an urban storm drain, creek, and ultimately to the Bay. Transport pathways in the urban landscape include vehicle tracking of road deposits, wind dispersal, foot tracking, and surface runoff (mainly from impervious surfaces) that feeds storm drains and creeks.

the converse is not true – industrial and commercial land uses are not always highly contaminated.

Variability in pollutant concentrations in samples taken at different times also poses challenges. Repeated sampling was conducted at only a few sites, but sites that once had high concentrations were not always high, and sites with low concentrations of pollutants in soils and sediments may not always be low. The largest potential problem is that a key hotspot might be missed in sampling. Understanding the causes of this variability will help stormwater agencies better design monitoring and management strategies.

Evaluation of Treatment Through Particle Settling

Laboratory studies of stormwater and sediments were conducted to determine the pollutant concentrations on sediment particles of different sizes. Developing this kind of data for local sites was a key recommendation from a comprehensive review of mercury and PCBs processes in the urban landscape. The reviewers recognized that this information would be useful in determining what control measures might be effective and how they might be best designed or implemented.

Data from the Bay and other areas indicate that chemical pollutants such as mercury and PCBs are primarily associated with fine-grained sediments, so it was hypothesized that control measures for contaminated urban sites would have to address this fraction of sediments. However, this hypothesis needed to be tested and refined since the geochemical environment of urban areas is quite different from that of the Bay. To this end, samples of stormwater flows were taken from two locations: the open channel of an urban watershed in Hayward (page 83) and an underground drainage pipe in Richmond.

Suspended sediment particles settle out of still waters at different rates, depending on their size, density, and shape. In the settling experiments, larger particles were separated from smaller ones by collecting material settled over different durations of time. Appropriate settling times for different particle-size fractions were based on their physical properties: 2 minutes for particles larger than 75 microns; 20 minutes for those between 25 and 75 microns; and over 20 minutes for particles smaller than 25 microns. The separated samples were analyzed for mercury and PCBs.

On average, less than 10% of mercury in a sample settled out within 2 minutes (TABLE 1). Even after 20 minutes of settling, an average of 80% or more of the mercury remained suspended or dissolved in the water column. In contrast, typically around 30% of the PCBs settled out within 2 minutes, and about half of the PCBs in stormwater samples settled out within 20 minutes.

However, for both pollutants, almost half the target load reductions (50% for mercury and 90% for PCBs) might be achieved with relatively short holding times in detention basins or other settling-based controls. The California Stormwater Quality Association (CASQA) stormwater BMP handbooks provide guidance on design size and capacity for treatment controls, with maximum holding times of 72 hours (for mosquito control) and suggest holding times of 24 hours or longer for "best water quality benefit" in controls such as wet ponds. If design capacities can routinely achieve such long holding times, settling-based control measures should show better removal performance than observed in these much shorter experiments.

	Minimum Removal	Maximum Removal	Average Removal
Mercury			
<2 min	3%	12%	7%
<20 min	10%	28%	17%
PCBs			
<2 min	14%	46%	31%
<20 min	27%	72%	53%

← TABLE 1

Mercury and PCB stormwater settling removal efficiencies, based on sampling at two Bay Area locations. Mercury loads in stormwater can potentially be reduced by around 20% with short holding times (20 minutes) in detention basins or other settling-based controls. PCB loads in stormwater can potentially be reduced by around 50% with similar holding times (20 minutes).

Modeling Evaluation to Predict Load Reduction

The potential application and effectiveness of a variety of BMP scenarios were evaluated using a simple spreadsheet model. The major inputs to the model were developed through the other project components. The outputs from the model were used to rank potential BMP scenarios for removing mercury and PCB mass over the next 20 years, and removal predictions were compared to the TMDL load reduction requirements.

The first step in the development of the model was to attribute the original source information in mass loads by land use (industrial, commercial, residential, or open/agriculture). The largest contribution of mercury loads to the Bay (excluding those from mines) probably comes from agriculture and open space areas, mainly due to the large area in these categories (**FIGURE 4**). In contrast, the largest loads of PCBs come from industrial areas (**FIGURE 5**). However, industrial and commercial areas had the most concentrated sources of both pollutants. Thus, industrial and commercial areas were classified as "high leverage" areas, where control measures are likely to be most cost effective.

The next step was to evaluate each BMP scenario. The BMP scenarios considered included:

- pollution prevention, such as fluorescent bulb recycling, thermostat recycling, and atmospheric source reductions for mercury, and building demolition and recovery for PCBs,

MERCURY

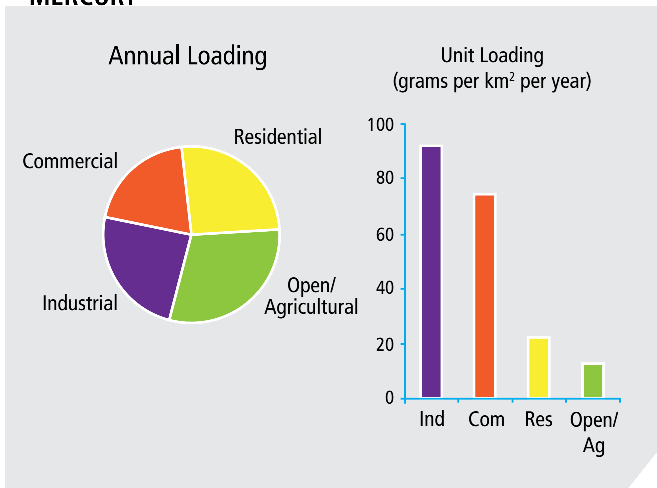


FIGURE 4
Annual mercury load and unit loading to the Bay Area stormwater system by land use. Although open space and agriculture provide the largest loads to the Bay, loads per unit area are about 7 times greater in industrial areas.

PCBs

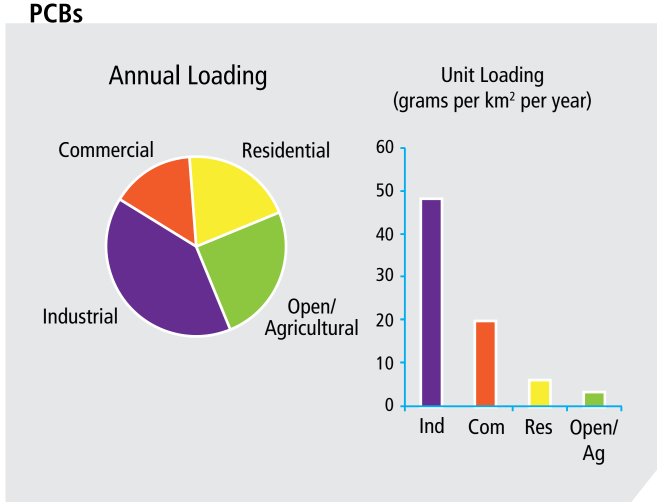


FIGURE 5
Annual PCB load and unit loading to the Bay Area stormwater system by land use. Industrial areas generate the largest annual loads, and a much higher load per unit area, making them clear priorities for management.

- maintenance such as street sweeping, street washing, and drop inlet cleaning, and
- treatment such as redevelopment, remediation or cleanup of elevated industrial areas, and pump station diversions to wastewater treatment plants.

For mercury, the model results suggested that the most effective scenarios were those that address source control and maintenance near the point of usage (air emissions control, mercury recycling, street sweeping, and drop inlet cleaning), with improved annual capture of up to 10 kg within the next 20 years. In contrast, for PCBs, the model predicted less than a 1 kg capture improvement in 20 years, with the most promising scenarios being capture of mass during building demolition and treatment of soils and runoff from high leverage areas. As high leverage areas are redeveloped, low impact development techniques (**Sidebar, page 12**) may provide means to capture not only mercury and PCBs but also other contaminants, such as PAHs, brominated flame retardants, and pesticides. Many of the effectiveness estimates for specific control measures have large uncertainties, so as more information is obtained from pilot studies conducted under the Municipal Regional Stormwater Permit (**page 8**), managers can continue to use and refine this modeling tool to adjust control strategies accordingly.

BMP Toolbox

The Regional BMP Evaluation included a synthesis of study findings and other recent relevant knowledge in a report: A BMP Toolbox for Reducing PCBs and Mercury in Municipal Stormwater. The toolbox provides guidance to stakeholders on how to locate and prevent mercury and PCBs from entering stormwater and reaching San Francisco Bay. It highlights opportunities for reducing loads for multiple other pollutants and for building on existing programs. The report is divided into sections on sources and pathways of PCBs and mercury in urban areas; BMPs for control of PCBs and mercury in municipal stormwater; and technical information and facts for design of BMPs.

The first section reviews key sources and transport pathways for these pollutants, providing the background behind the need for pollutant-specific approaches. Although there are many advantages to managing PCBs and mercury together, no single set of BMPs will suffice. Regional and local strategies for these and other pollutants will therefore differ and need to draw on a full range of BMP options. Luckily, many stormwater programs have experience of implementing BMPs to control sediments and other pollutants. Controlling PCBs and mercury can be thought of as an enhancement of these existing programs, and measures of programmatic effectiveness can be built upon measures already in place.

The main section of the BMP Toolbox condenses the results of the modeling evaluation of BMP scenarios and characterization studies, along with other information, into a set of fact sheets targeted at stormwater managers. Each fact sheet describes the BMP; discusses implementation locations and applicability, design considerations, information needs and uncertainties; and provides references and a list of additional information sources. The fact sheets will be updated as new technologies are developed, more local information is accumulated through the BASMAA USEPA grant Clean Watersheds for a Clean Bay, and municipal regional stormwater permittees evaluate the efficacy of BMPs for reducing loads of PCBs and mercury.

A Promising Beginning

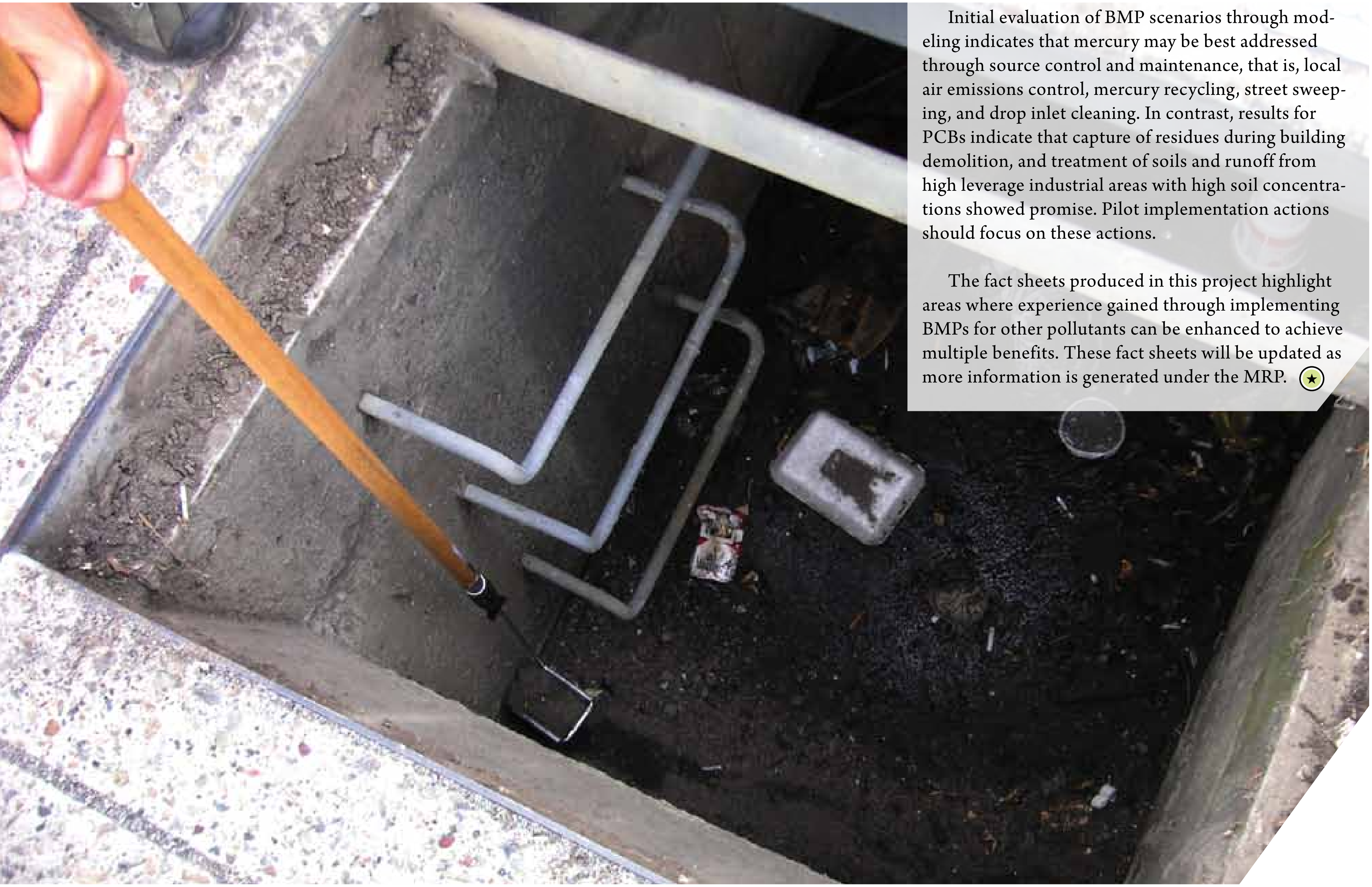
Although the Bay Area is very early in the process of achieving long-term goals of reducing mercury and PCB loads from urban stormwater, results from the Regional BMP Evaluation are promising. Pollution prevention is an important first step, as ounces of prevention are worth tons of cure. For contaminants already out in the urban landscape, there is also hope.

PCBs and mercury are not uniformly distributed in the urban environment, so at least initially, stormwater agencies may choose to focus control measures on more contaminated, high leverage sites, where benefits will be larger and more easily measurable. As needs are identified, more extensive or elaborate control measures may be considered and implemented.

Treatment of all urban stormwater, all the time, may not be needed to achieve TMDL load reductions. If treatment controls are implemented, half of the PCBs transported in urban stormwater appear to be removable relatively quickly via settling or other controls that remove moderate size particles. In contrast, most mercury in stormwater is dissolved or on small particles, so removal from urban stormwater will be more difficult.

Initial evaluation of BMP scenarios through modeling indicates that mercury may be best addressed through source control and maintenance, that is, local air emissions control, mercury recycling, street sweeping, and drop inlet cleaning. In contrast, results for PCBs indicate that capture of residues during building demolition, and treatment of soils and runoff from high leverage industrial areas with high soil concentrations showed promise. Pilot implementation actions should focus on these actions.

The fact sheets produced in this project highlight areas where experience gained through implementing BMPs for other pollutants can be enhanced to achieve multiple benefits. These fact sheets will be updated as more information is generated under the MRP. ★



↑ Sampling sediment from a storm drain inlet. Photograph by Lester McKee.

LINKING THE WATERSHEDS AND THE BAY IN THE RMP: THE SMALL TRIBUTARY LOADING STRATEGY

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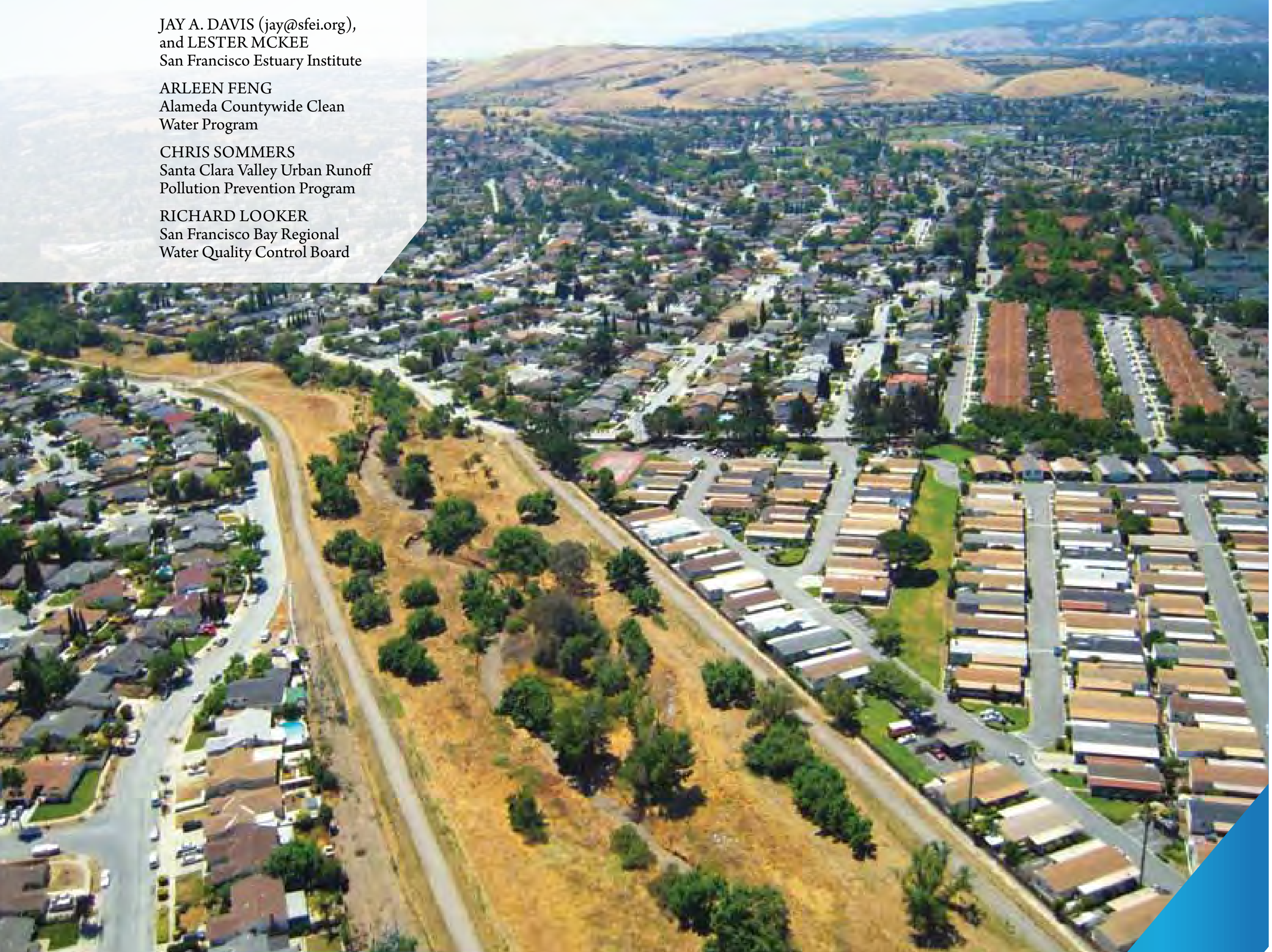


Highlights

- Small tributaries have become a focal point of strategies to reduce contaminant inputs to San Francisco Bay
- The state of knowledge on contaminant loads from small tributaries remains rudimentary
- Two significant and related initiatives to address these information needs have taken shape in the past year: the Municipal Regional Stormwater Permit and the RMP Small Tributary Loading Strategy
- Initial work under the Small Tributary Loading Strategy will develop a multi-year overarching, coordinated blueprint for monitoring under the RMP and the Municipal Regional Permit
- The primary emphasis of the Strategy, with an RMP investment of over $1 million over the next four years, will be monitoring contaminant loads in repre-sentative small tributaries

Aerial view of Thompson Creek in southeastern San Jose. Photograph by Jay Davis.

Small Tributaries, Large Loads

San Francisco Bay receives freshwater flows from a wide spectrum of tributaries, ranging from the great Sacramento River – the second largest river flowing to the Pacific Ocean from the U.S. – to the many small creeks and storm drains that perforate the Bay shoreline (**FIGURE 1A,B,C**). All of these tributaries, to some degree, carry contaminants into the Bay. The Sacramento River has long been known to carry a large proportion of the overall contaminant load. In recent years research has made it increasingly clear that other tributaries, referred to in the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) as "small tributaries," also carry substantial loads (**page 80**). Included in this category are several prominent water bodies such as Alameda Creek, the Petaluma and Napa rivers, and Coyote Creek, in addition to hundreds of smaller creeks and storm drains.

The Bay's rivers, creeks, and streams themselves are valuable ecosystems that provide important habitat and are affected by contaminants and other stressors. However, the focus of this article is on managing the contaminant loads carried to the Bay by these water bodies. Efforts to evaluate conditions in Bay Area small tributaries are described in another article in this edition of *The Pulse of the Estuary* (**page 68**).

Small tributaries are a pathway through which urban and non-urban stormwater enters San Francisco Bay. The contaminant loads conveyed by small tributaries are significant not only because of their magnitude, but also because of their proximity to the margins of the Bay, where the levels of many contaminants are highest. These high levels are likely partially due to sediment particles transported by small tributaries settling out on the margins as concentrated freshwater flows are dispersed in the broader saline waters of the Bay.

The RMP has developed a Small Tributary Loading Strategy to support management efforts to reduce inputs of mercury, PCBs, and other contaminants to the Bay from stormwater

The small tributary pathway has become a focal point in plans to reduce contaminant inputs to the Bay. The TMDLs for mercury and polychlorinated biphenyls (PCBs) have both called for significant reductions in loads from stormwater carried by small tributaries (**FIGURE 2**). The mercury TMDL specifically calls for a 49% reduction in loads from urban stormwater. The PCB TMDL does not separate urban and non-urban stormwater, but does stipulate a 90% reduction in loads from stormwater. The PCB reduction goal primarily applies to urban stormwater, as PCBs are predominantly urban contaminants. Urban stormwater is likely also a significant pathway for many other contaminants of concern in the Bay, including dioxins, pesticides, polycyclic aromatic hydrocarbons (PAHs), trash, copper, and polybrominated diphenyl ethers (PBDEs).

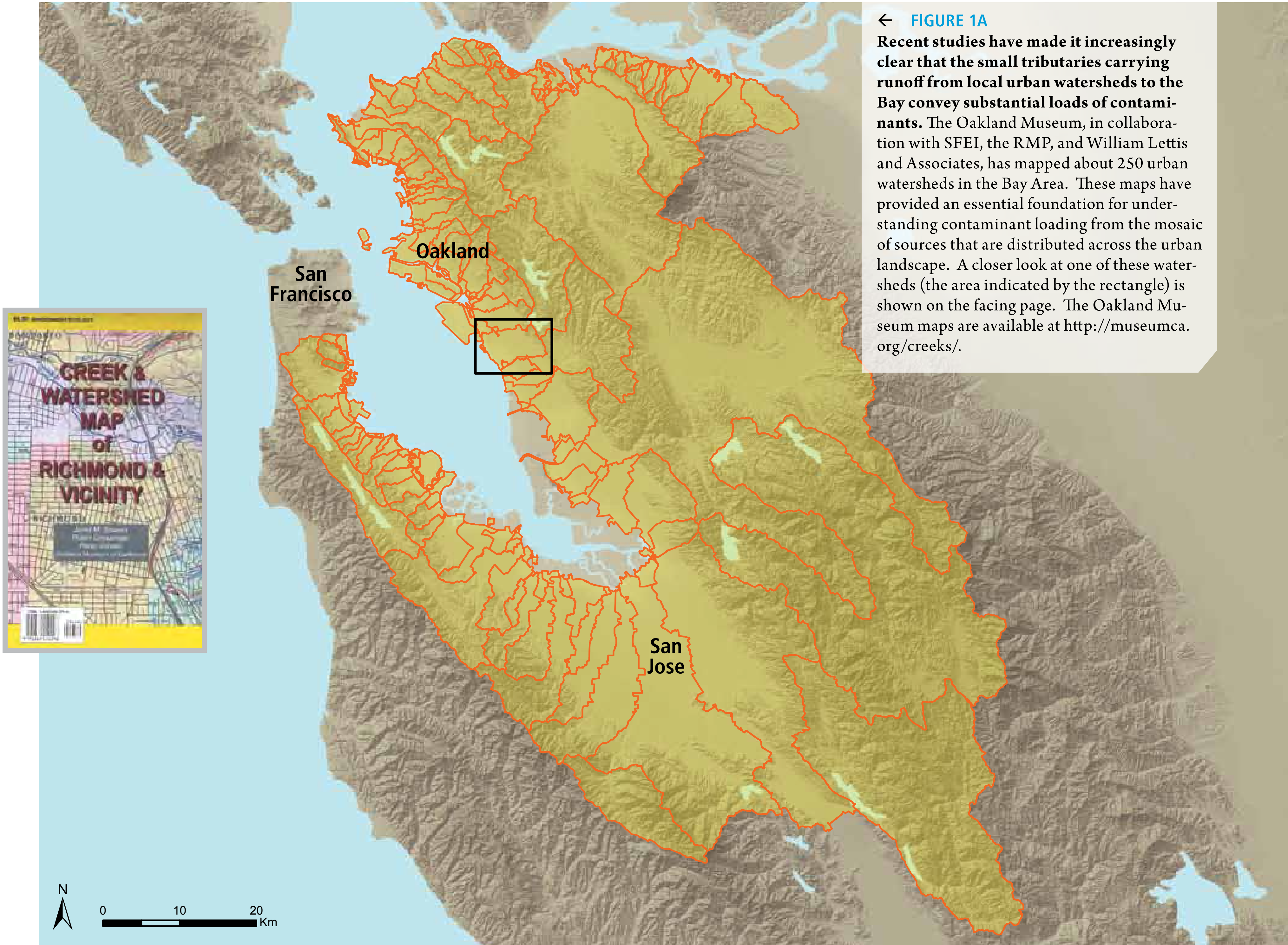
The RMP has developed a Small Tributary Loading Strategy to support management efforts to reduce inputs of mercury, PCBs, and other contaminants to the Bay from stormwater. This article provides an overview of the Strategy and the impetus behind it.

Information Needs

In spite of the large influence of small tributaries on Bay water quality, the state of knowledge on contaminant loads from this pathway remains rudimentary. Significant uncertainty surrounds many basic and critical topics, such as:

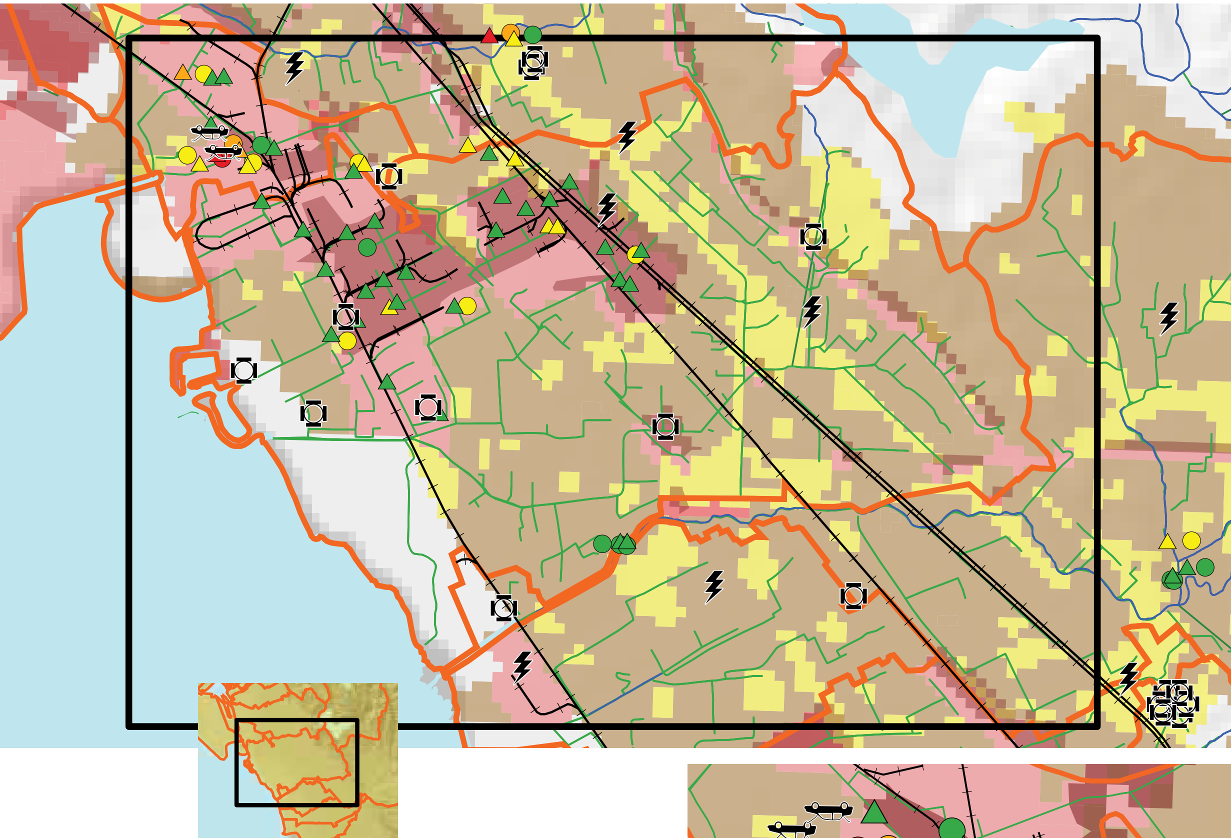
- the overall magnitude of small tributary loads to the Bay;
- long-term trends in small tributary loads individually and collectively;
- which watersheds contribute most to water quality impacts on local and regional scales; and
- how managers can most effectively reduce the impacts of small tributaries on Bay water quality.

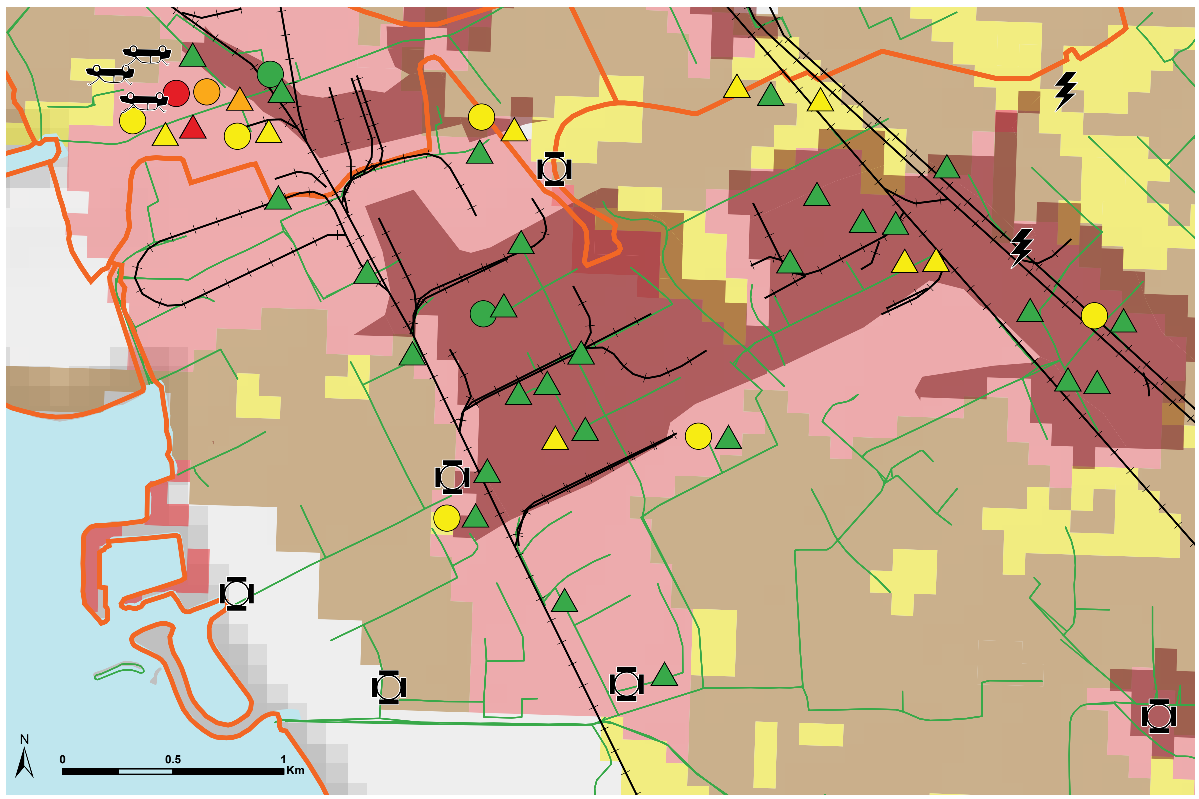
Two primary reasons explain the lack of progress to date in understanding small tributary loads. First, stormwater loads are very challenging and expensive to monitor and manage. Factors contributing to this are the diffuse distribution of sources of contamination throughout Bay Area watersheds, the large number of creeks and storm drains that must be considered, and the highly sporadic nature of storms



← **FIGURE 1A**

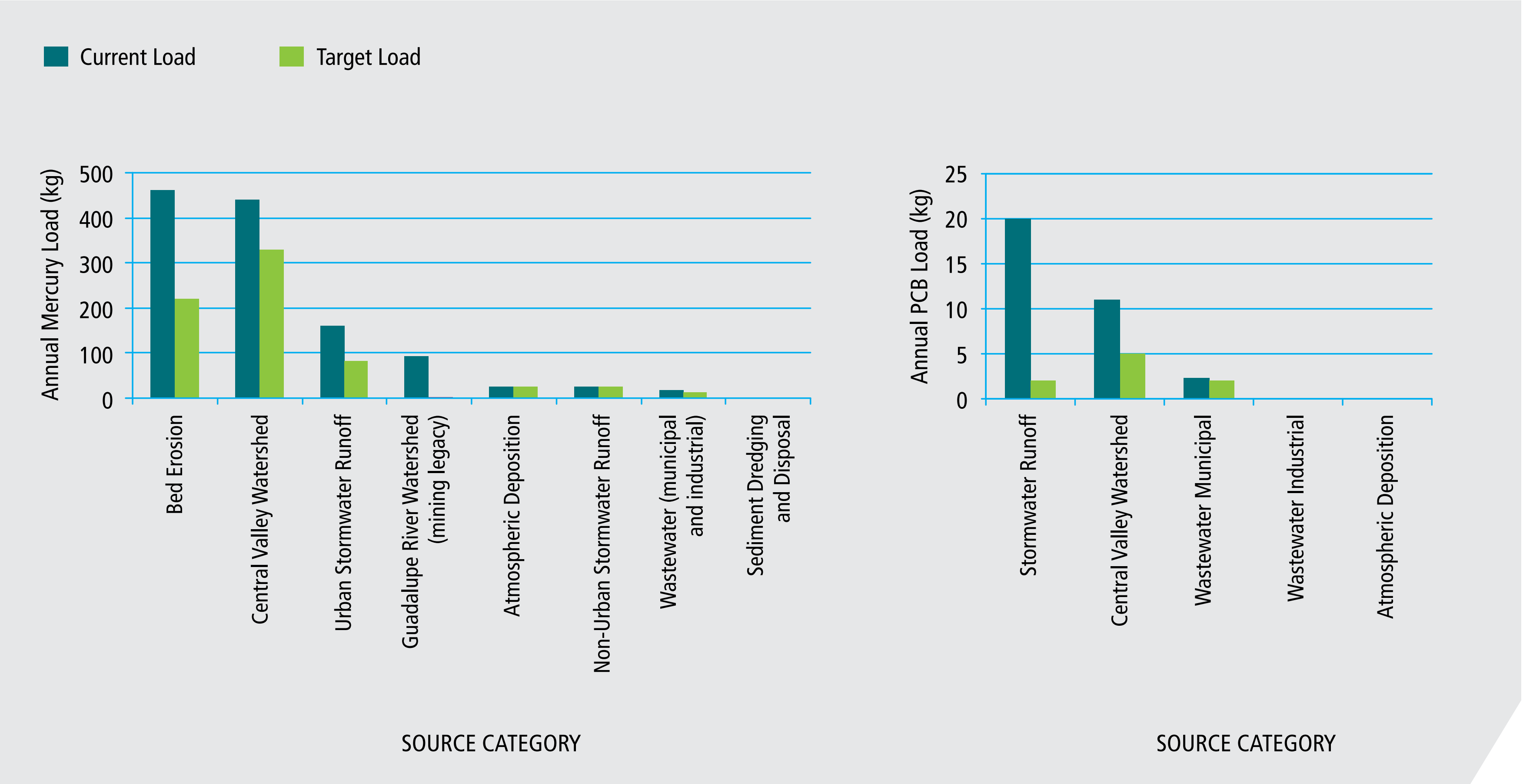
Recent studies have made it increasingly clear that the small tributaries carrying runoff from local urban watersheds to the Bay convey substantial loads of contaminants. The Oakland Museum, in collaboration with SFEI, the RMP, and William Lettis and Associates, has mapped about 250 urban watersheds in the Bay Area. These maps have provided an essential foundation for understanding contaminant loading from the mosaic of sources that are distributed across the urban landscape. A closer look at one of these watersheds (the area indicated by the rectangle) is shown on the facing page. The Oakland Museum maps are available at http://museumca.org/creeks/.





FIGURES 1B ↑ AND 1C →

Land use, drainage network, and contaminant concentrations in a San Leandro watershed. Detailed information on many Bay Area watersheds was compiled as part of a recent SFEI study of stormwater management options (page 20). The storm drain network, including drains 24 inches and greater in diameter, is shown in green. With this network mapped, water flow can be tracked even if it is sometimes underground and hidden from view. High concentrations of mercury and PCBs in storm drain sediments (orange and red symbols) often occur in industrial areas. An example can be seen most clearly in the upper left of the lower map.



↑ **FIGURE 2**

The small tributary pathway has become a focal point in plans to reduce contaminant inputs to the Bay. The TMDLs for mercury and PCBs have both called for significant reductions in loads from stormwater carried by small tributaries. The mercury TMDL specifically requires a 49% reduction in loads from urban stormwater. The PCB TMDL does not separate urban and nonurban stormwater, but does stipulate a 90% reduction in loads from stormwater. The PCB reduction goal primarily applies to urban stormwater, as PCBs are predominantly urban contaminants. Urban runoff is also a significant source of many other contaminants of concern, including dioxins, pesticides, PAHs, trash, copper, and PBDEs.

A pragmatic approach to estimating regional urban stormwater loads would be to gather information from a few carefully selected, representative watersheds and to extrapolate results to the unmonitored watersheds through modeling

and stormwater transport. Second, early regulatory efforts to implement provisions of the 1972 Clean Water Act focused on municipal and industrial effluents. Attention began to shift to stormwater in the late 1980s, leading to the adoption of the first municipal stormwater permits in the nation in the early 1990s, and subsequently the Municipal Regional Stormwater Permit in 2009 (**page 8**).

Estimates of small tributary loads to date have primarily been generated using simple modeling approaches, based on compilations of existing information that incorporated major simplifying assumptions and produced highly uncertain results. These preliminary estimates of loads do not provide a sound basis for stormwater management decisions at the regional level. A more accurate approach to estimating loads is to measure them directly through monitoring and extrapolate these data more broadly using modeling techniques. In 2001 the RMP began direct measurement in two watersheds, and this approach has generated a great deal of useful information (**page 80**). Monitoring loads in this manner in every small tributary would be prohibitively expensive, but there is a clear need for more information based on direct measurements.

Effective and efficient management of stormwater loads in the region will require a solid foundation of monitoring coupled with models that allow for credible extrapolation of the empirical results to all Bay Area small tributaries. A pragmatic approach to estimating regional urban stormwater loads would be to gather information from a few carefully selected, representative watersheds and to extrapolate results to the unmonitored watersheds through modeling.

Information Is On The Way

Two significant and related initiatives to address these information needs have taken shape in the past year. The first is the Municipal Regional Stormwater Permit (**page 8**), which requires Bay Area municipalities to conduct small tributary load monitoring at eight locations, in addition to other monitoring provisions. In fulfilling these requirements, these municipalities will greatly increase the information base needed for regional stormwater management.

The other major initiative to address regional information needs on small tributary loads is the Small Tributary Loading Strategy of the Regional Monitoring Program (RMP). The Small Tributary Loading Strategy is one of several strategies that have been developed by the RMP to address high priority water quality issues. RMP strategies have also been developed for mercury (Davis et al. 2008), PCBs, dioxins, emerging contaminants, exposure and effects, and forecasting. These strategies are all components of the RMP Master Plan, a document that provides a succinct but overarching description of the priorities, directions, and elements of the Program for the next five years (**Sidebar**).

Each RMP strategy includes the same basic components. First, for each high priority topic, management policies or decisions that are anticipated to occur in the next few years are identified. Second, the latest advances in understanding that have been achieved through the RMP and other programs are summarized. Third, led by the stakeholder representatives that participate in these groups, each workgroup and team develops a specific list of high priority questions that the RMP will strive to answer over the next five years. Fourth, with guidance from the science advisors on each group, plans are developed to address these questions. These plans are presented in the form of annual budgets. Additional context is also provided by listing studies performed within the last two years and studies that are currently underway.

The Small Tributary Loading Strategy

The Small Tributary Loading Strategy was developed to ensure that the RMP is providing the information most urgently needed by managers to reduce loads and impacts of pollutants of concern entering the Bay from small tributaries. The Strategy is summarized on pages 38 and 39.

PRIORITY QUESTIONS

Question 1

Which are the "high-leverage" small tributaries that contribute or potentially contribute most to Bay impairment by pollutants of concern?

An understanding of the contributions of individual small tributaries to Bay impairment will be essential to developing cost-effective strategies for reducing loads and impacts in sensitive areas on the margins of the Bay. This question relates closely to the RMP strategies for Mercury, PCBs, and Forecasting, which have identified the need to determine which loading pathways disproportionately contribute to food web accumulation. Before monitoring and more extensive gathering of empirical data can begin, initial decisions must be made about which small tributaries to study. In other words, a thoughtful attempt must be made to identify small tributaries that are high priorities for monitoring, including consideration of their influence on impairment, based on available information.

Question 2

What are the loads or concentrations of pollutants of concern from small tributaries to the Bay?

The TMDLs for mercury and PCBs include an allocation for the aggregate loads from urban stormwater. Data collected in compliance with the Municipal Regional Permit and by the RMP will provide improved estimates of loads from monitoring of individual tributaries that can be aggregated to make regional estimates. This information will also be useful for input into models of Bay impairment and recovery time. Models will also be needed to estimate regional urban stormwater loads by extrapolating empirical data from monitored tributaries to other unmonitored tributaries. Although mercury and PCBs are the highest priorities for investigation, regional loading estimates are also needed for other contaminants (e.g., selenium and legacy pesticides).

A few key immediate questions must be answered. For example, what is the best monitoring design to obtain loading information? How many categories of watersheds are there in the Bay Area? How many watersheds in each category should be studied? Which categories should be prioritized for initial study?

Question 3

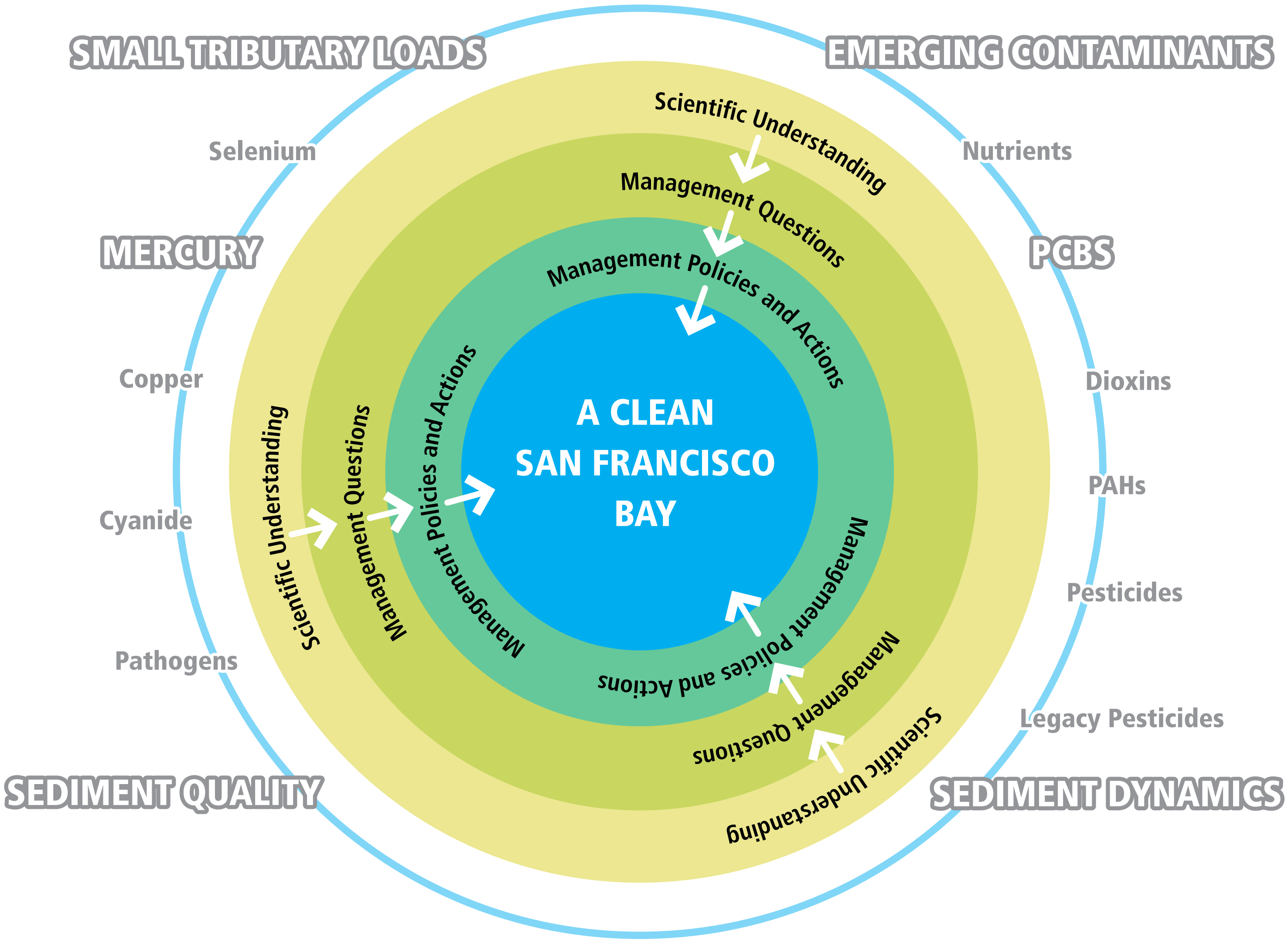
How are loads or concentrations of pollutants of concern from small tributaries changing on a decadal scale?

As stated in the Municipal Regional Permit, understanding long-term trends in loads is essential to tracking progress toward TMDL wasteload allocations. Answering this question will require the systematic collection of data from fixed locations. Statistical analysis will be needed to determine the amount of data required to see a trend of a given magnitude, based on reasonable expectations of management effort and environmental variability.

Question 4

What are the projected impacts of management actions on loads or concentrations of pollutants of concern from the high-leverage small tributaries?

The Municipal Regional Permit outlines a number of specific control measures to reduce mercury and PCB loads in urban stormwater. Answering this question will require conceptual and quantitative models of the behavior of contaminants in the watersheds, built on an adequate foundation of empirical information. Empirical data will be needed as inputs for the models, as well as for evaluation of model performance. Information on anticipated management actions will also be needed so that studies can be performed to guide those actions.



THE RMP MASTER PLAN

The RMP is developing a new document, the RMP Master Plan, that provides a succinct but overarching description of the priorities, directions, and elements of the Program for the next five years. The Master Plan is built on the efforts of many workgroups and strategy teams that have developed five-year plans for studies to address the highest priority management questions for their subject areas. Collectively, the efforts of all these groups represent quite a substantial body of deliberation and planning. The goal of these extensive planning efforts is to support a Program that is forward-looking and anticipates decisions and policies that are on the horizon, so that when their time comes the scientific knowledge needed to inform the decisions is on hand. Hockey player Wayne Gretzky expressed this concept well: "A good hockey player plays where the puck is. A great hockey player plays where the puck is going to be." The Master Plan will be completed in late 2010.

THE RMP SMALL TRIBUTARY LOADING STRATEGY

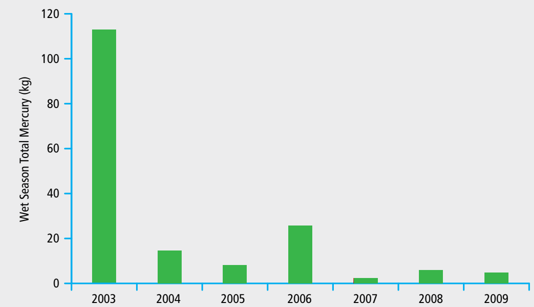
Relevant Management Policies and Decisions

- **Provisions of the Municipal Regional Permit in 2010 and beyond**
- **The next iteration of the mercury and PCBs TMDLs in 2016-2020**
- **Potential TMDLs for other contaminants**
- **Which small tributaries and associated watersheds are the highest priorities for management?**
- **What management actions are the best options for small tributaries?**

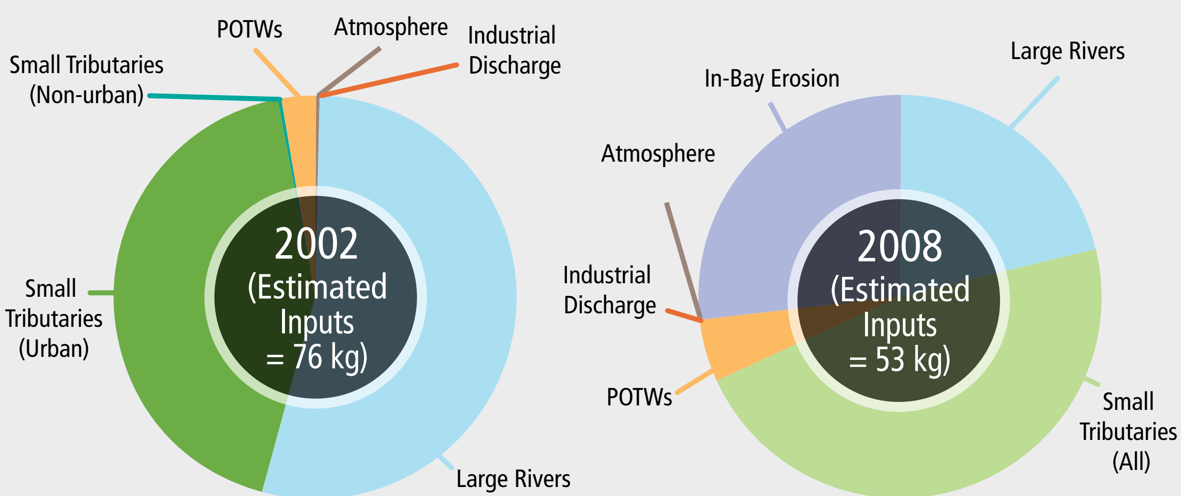
Recent Noteworthy Findings

- **The relative magnitude of estimated small tributary loads has increased dramatically for PCBs and mercury as we have obtained better information over the past eight years.**
- **More intense rainfall in the New Almaden historic mining district mobilizes sediment particles with high mercury concentrations.**
- **PCBs in the Guadalupe River watershed predominantly originate from urbanized areas in the lower watershed.**
- **Distinct differences in wet and dry years lead to high variability in mercury loadings to the Bay.**
- **Area-scaled loadings of many pollutants were similar for the Guadalupe watershed and for a small highly urbanized watershed in Hayward.**

Mercury from the Guadalupe River



Estimates of PCB loads to the Bay in 2002 and 2008



Priority Questions for the Next Five Years

1. **Which are the "high-leverage" small tributaries that contribute or potentially contribute most to Bay impairment by pollutants of concern?**
2. **What are the loads or concentrations of pollutants of concern from small tributaries to the Bay?**
3. **How are loads or concentrations of pollutants of concern from small tributaries changing on a decadal scale?**
4. **What are the projected impacts of management actions on loads or concentrations of pollutants of concern from the high-leverage small tributaries?**

THE RMP SMALL TRIBUTARY LOADING STRATEGY

Small Tributary Loading Strategy studies began in 2008. Monitoring loads from representative watersheds will be the major emphasis for the next several years. Monitoring of representative source characterization sites in 2012 and beyond will provide data needed for model development in subsequent years.

Small tributary loading studies in the RMP from 2008 to 2015. Numbers indicate preliminary budget allocations in $1000s.

General Area	Element	STLS Questions Addressed	2008	2009	2010	2011	2012	2013	2014	2015
Synthesis	Develop Multi-Year Watershed Loading Sampling Plan	1,2,3,4,5		80						
	Regional Loadings Estimates (Spreadsheet Model)	1,2,3,4,5	40		35	20	20	20	20	TBD
Monitoring	Zone 4 Small Tributaries Loading Study (Status and Trends)	1,2,3	100	100	151					
	POC Load Monitoring in Representative Watersheds	1,2,3			87	300	300	300	300	TBD
	Monitoring at Representative Source Characterization Sites	1,2,3,4,5				20	80	100	100	TBD
Modeling	Guadalupe River Model	4,5	75	75						
	Dynamic Modeling in a 2nd Selected Representative Watershed	4,5					150			
	Additional Watershed Model	4,5						75		
	Large Scale Watershed Model	4,5							TBD	TBD

Getting the Answers

RMP plans for small tributary loading studies are shown on **page 39**. These plans and the Small Tributary Loading Strategy as a whole will be updated annually as management needs evolve, questions are answered, new questions arise, and the optimal path forward becomes clearer.

Developing a Multi-Year Sampling Plan

The initial emphasis of the Strategy in 2009 and 2010 has been to develop a Multi-Year Sampling Plan that provides an overarching, coordinated blueprint for pollutant of concern monitoring that will occur under the RMP and the Municipal Regional Permit. The Sampling Plan will be developed through ongoing discussions among the Water Board, the Bay Area Stormwater Management Agencies Association (BASMAA), and scientific experts on stormwater monitoring.

Three tasks are contributing to the development of the Sampling Plan. The first is to develop and apply a scheme for prioritizing small tributaries for monitoring. Two key questions are how many types of watersheds exist in the Bay Area and how many should be studied to answer key management questions? A long-standing recommendation of the RMP Sources, Pathways, and Loadings Workgroup is to classify watersheds into broad categories and then to sample one or two tributaries in each category. However, due to budget limitations, this need remains unfulfilled. To classify and rank watersheds, information on the location and abundance of known PCB and mercury sources, land use characteristics, and imperviousness will be combined with recent estimates of sediment loads. Other criteria to be used in the prioritization process include connectivity with contaminated Bay margin areas, anticipated locations of management actions, opportunities for collaboration, and benefits for multiple pollutants.

The second task is to determine optimal methods for monitoring loadings and trends. Management questions that are evaluated by monitoring require a sampling design that is cost-effective and provides the information needed with an adequate degree of confidence. Using data collected on two tributaries already monitored by the RMP (**page 80**), an analysis is being performed on scenarios of sampling frequency, number of samples, and sampling methodology to accurately assess loads and determine trends, while minimizing costs.

The third task is to develop a simple "spreadsheet model" to generate regional loading estimates. Spreadsheet models are a useful and inexpensive tool for this purpose. They are based on the simplistic assumption that runoff from homogeneous subcatchments of a watershed have consistent contaminant concentrations. That simplification gives spreadsheet models a major advantage over more elaborate models that require large calibration data sets, which are challenging to collect. A spreadsheet model was developed for the Bay Area previously (Davis et al. 2000). However, at that time, local source-specific contaminant data were only available for a drought period in the late 1980s and early 1990s, and no data were available for mercury and PCBs. In this task, a GIS-based spreadsheet model is being developed using more recent local data on source-specific concentrations and loads collected in the Bay Area, to be augmented with recent stormwater data from elsewhere. The spreadsheet model will be updated annually as data become available through implementation of the Strategy.

A Major Investment in Loads Monitoring

The primary emphasis of the Small Tributary Loading Strategy for the next five years will be monitoring contaminant loads at representative tributaries identified in the Multi-Year Sampling Plan. This monitoring will be critically important to answering all of the questions articulated in the Strategy. The plan calls for the RMP to spend over $1 million over the next four years to obtain this loading information. This represents a significant proportion of the $13 million budget of the RMP as a whole over that period. This level of funding should be sufficient to cover a portion of the pollutant of concern loads monitoring called for in the Municipal Regional Permit. The rest of the required monitoring will be performed by the permit holders in close coordination with the RMP.

Extrapolation and Forecasting

Extrapolation will be needed to take the empirical information obtained from monitoring selected watersheds and make general estimates of loading from small tributaries as a whole. Forecasting will be needed to help managers decide which actions will be most effective in reducing Bay impairment. Both extrapolation and forecasting will be achieved through the use of models. The remaining tasks included in the Small Tributary Loading Strategy all relate to the development of these models.

Monitoring at representative source characterization sites will address an important information gap for the Bay Area. This information will be useful in both extrapolation to unmonitored watersheds and dynamic models used in forecasting. The monitoring would entail sampling stormwater contaminant concentrations and loads at sites representing different sources. Because this monitoring is expected to be relatively expensive, further deliberation is needed to determine which types of sites to focus on and the type of sampling methods to use in the field. A cost-effective monitoring plan will be developed based on the findings from tasks conducted during the development of the Multi-Year Sampling Plan and careful review of existing data from the Bay Area and elsewhere.

↖ Stormwater sampling at Zone 4, Line A in Hayward. Photograph by Sarah Pearce.

The last major component of the Strategy is to further develop dynamic models of contaminant transport within watersheds and loading to the Bay. Dynamic watershed models combine spatial information on the distribution of important features (such as land uses, contaminant sources, rainfall, and waterways) throughout the watershed with estimates of the rates of processes that move contaminants into and across the landscape (including deposition from the atmosphere, releases from sources, mobilization by stormwater, and deposition and resuspension in creeks and streams) in order to predict contaminant transport to downstream receiving waters. This type of model is referred to as a mechanistic model. Mechanistic models can predict the effectiveness of management actions (for example, redevelopment of an industrial area) and the magnitude of actions needed to see measurable load reductions at the watershed and regional scales. These models will also help prioritize remaining information gaps by identifying variables that have the greatest influence on predicted outcomes.

The RMP began dynamic watershed model development with a pilot effort in the Guadalupe River Watershed with funds from 2008 and 2009 (**page 80**). This watershed offers a unique opportunity to study legacy mercury from the largest-producing historic mining district in North America as well as legacy PCBs from the industrial activities of the 1950s, 1960s, and 1970s. An abundance of local water, sediment, and contaminant data also made this watershed a logical place to begin mechanistic modeling. Work on the Guadalupe watershed model will be completed in 2010. The Small Tributary Loading Strategy calls for additional dynamic model development in 2012, after field studies generate a better foundation of the data needed to drive these models. Under current plans, dynamic models will be developed for additional watersheds over time, ultimately leading to a model that can be used at a broader regional scale.

A Large Leap Forward

The RMP Small Tributary Loading Strategy is helping to establish a clear direction for obtaining the information water quality managers need to support a concerted effort to reduce contaminant loading to the Bay from this important pathway. The Strategy will help establish a process and a plan to ensure that resources are available to obtain loading information in an effective and efficient manner over the next several years. These efforts will establish a vastly improved body of empirical information on urban stormwater loading in the Bay Area. Through thoughtful planning, the data gathering will include the parameters needed to drive the models that will be used in the future to generate improved estimates of loads at a regional scale and to project future trends in response to management actions. The monitoring data and models will answer the critical questions regarding small tributary loads, allowing for effective and efficient reductions in loads and improvements in Bay water quality.

THE 303(D) LIST

SECTION 303(D) OF THE 1972 FEDERAL CLEAN WATER ACT requires that states develop a list of water bodies that do not meet water quality standards, establish priority rankings for waters on the list, and develop action plans, called Total Maximum Daily Loads (TMDLs), to improve water quality. The list of impaired water bodies is revised periodically (typically every two years). The RMP is one of many entities that provide data to the State Water Board to compile the 303(d) List and to develop TMDLs.

The process for developing the 303(d) List for the Bay includes the following steps:

- development of a draft List by the San Francisco Bay Regional Water Board;
- adoption by the State Water Board; and
- approval by USEPA.

In August 2010, the State Water Board adopted the 2010 303(d) List. The 2010 List was then transmitted to USEPA for final approval.

The Regional Water Board and State Water Board are now working developing the draft 2012 303(d) List.

The primary pollutants/stressors for the Estuary and its major tributaries on the 2010 303(d) List include:

Trace elements
Mercury and Selenium

Pesticides
Dieldrin, Chlordane, and DDT

Other chlorinated compounds
PCBs, Dioxin and Furan Compounds

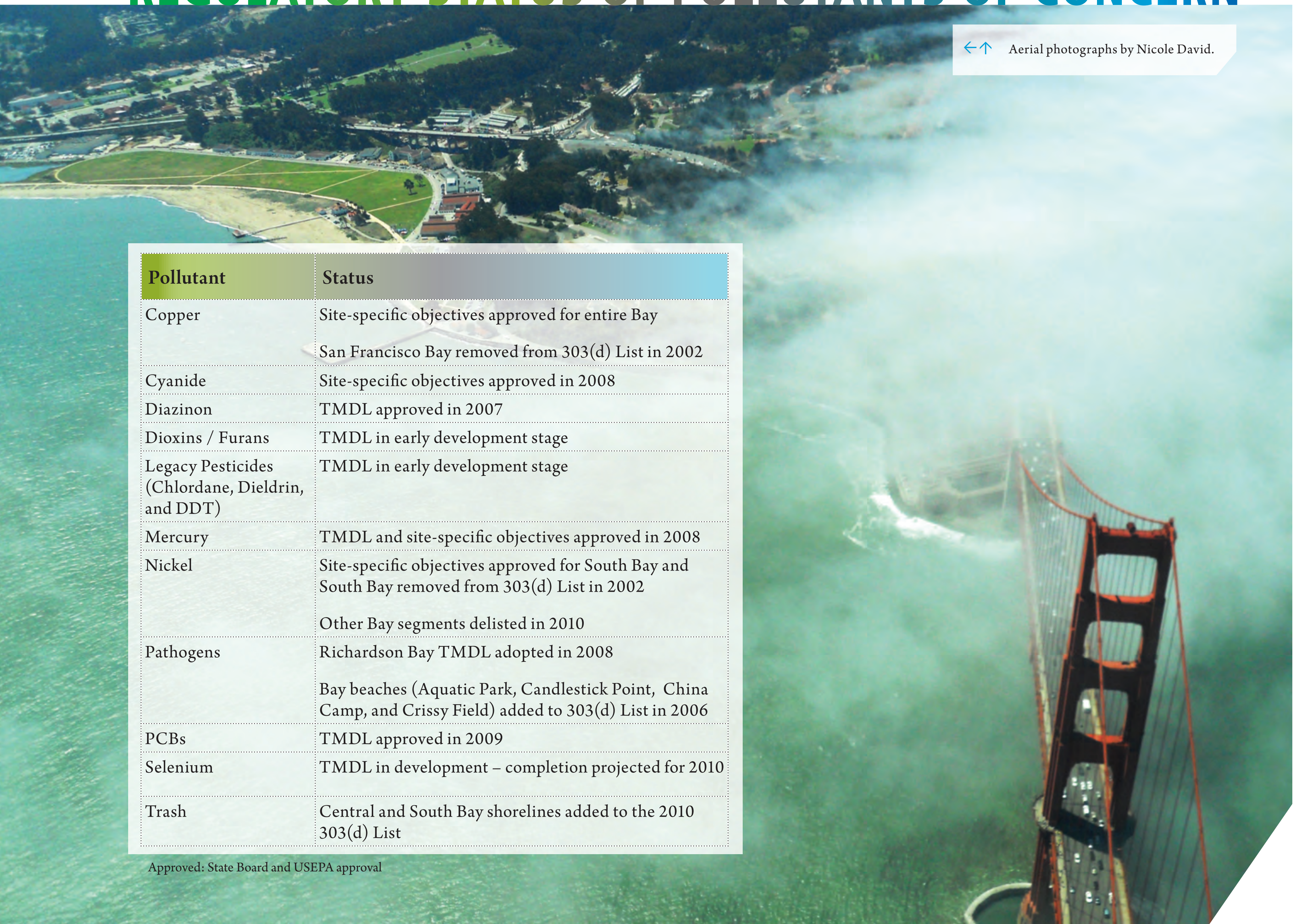
Others
Exotic Species, Trash, and Polycyclic Aromatic Hydrocarbons (PAHs)

More information on the 303(d) List and TMDLs is available from the following websites

303(d) List for Region 2 (which includes the Estuary)
www.waterboards.ca.gov/sanfranciscobay/water_issues/ programs/TMDLs/303dlist.shtml

TMDLs
www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs, www.water.epa.gov/lawsregs/lawguidance/cwa/tmdl/index.ctm

REGULATORY STATUS OF POLLUTANTS OF CONCERN



Aerial photographs by Nicole David.

Pollutant	Status
Copper	Site-specific objectives approved for entire Bay San Francisco Bay removed from 303(d) List in 2002
Cyanide	Site-specific objectives approved in 2008
Diazinon	TMDL approved in 2007
Dioxins / Furans	TMDL in early development stage
Legacy Pesticides (Chlordane, Dieldrin, and DDT)	TMDL in early development stage
Mercury	TMDL and site-specific objectives approved in 2008
Nickel	Site-specific objectives approved for South Bay and South Bay removed from 303(d) List in 2002 Other Bay segments delisted in 2010
Pathogens	Richardson Bay TMDL adopted in 2008 Bay beaches (Aquatic Park, Candlestick Point, China Camp, and Crissy Field) added to 303(d) List in 2006
PCBs	TMDL approved in 2009
Selenium	TMDL in development – completion projected for 2010
Trash	Central and South Bay shorelines added to the 2010 303(d) List

Approved: State Board and USEPA approval

46 THE LATEST MONITORING RESULTS

STATUS AND TRENDS UPDATE

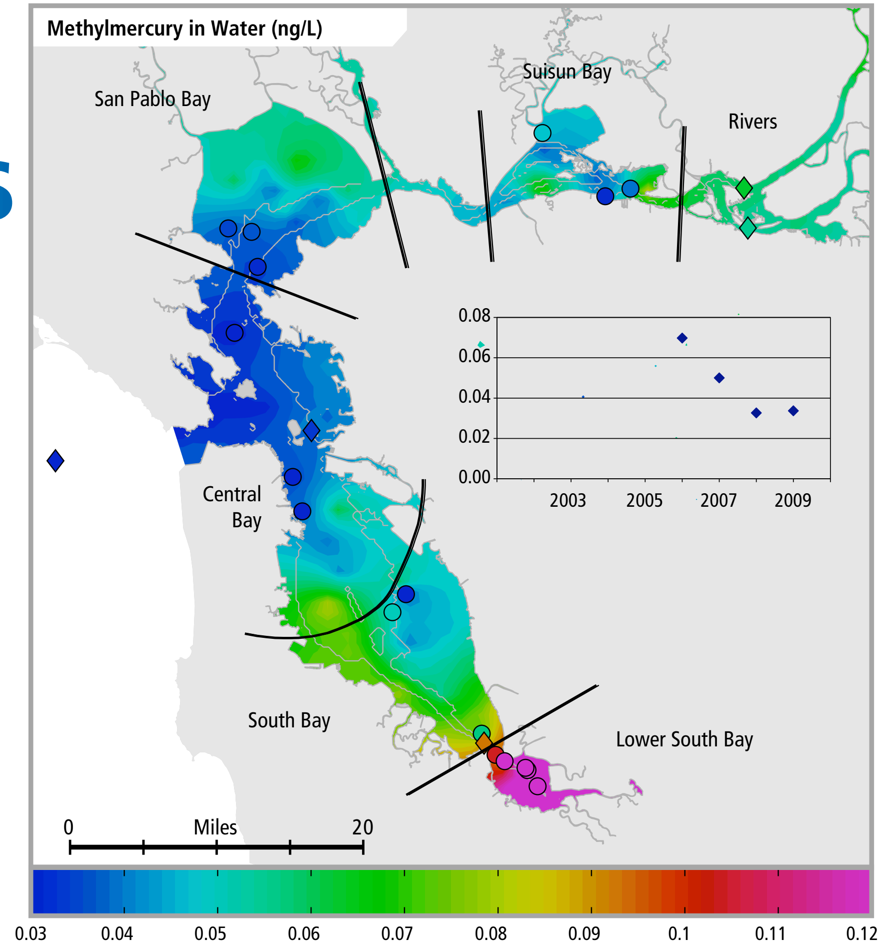
58 WATER QUALITY TRENDS AT A GLANCE

↑ Views of Pinole Creek. Photographs by Sarah Pearce.

THE LATEST MONITORING RESULTS

MERCURY

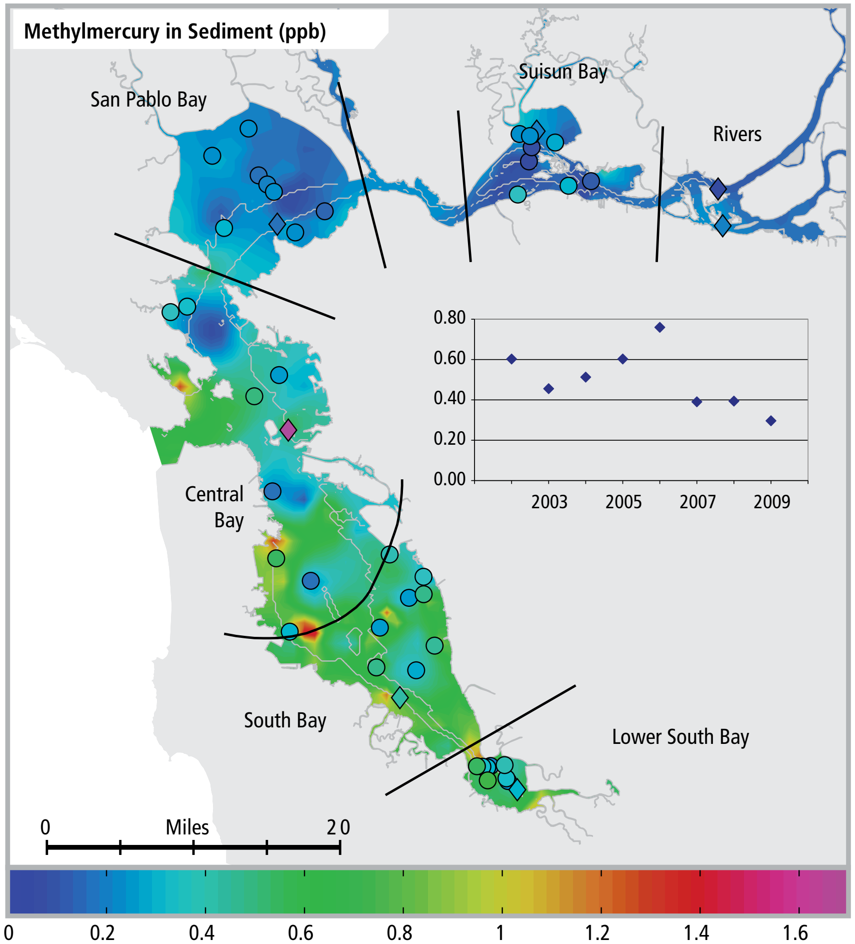
Mercury contamination is one of the top water quality concerns in the Estuary and mercury clean-up is a high priority of the Water Board. Mercury is a problem because it accumulates to high concentrations and poses risks to some fish and wildlife species. The greatest health risks from mercury are generally faced by humans and wildlife that consume fish.



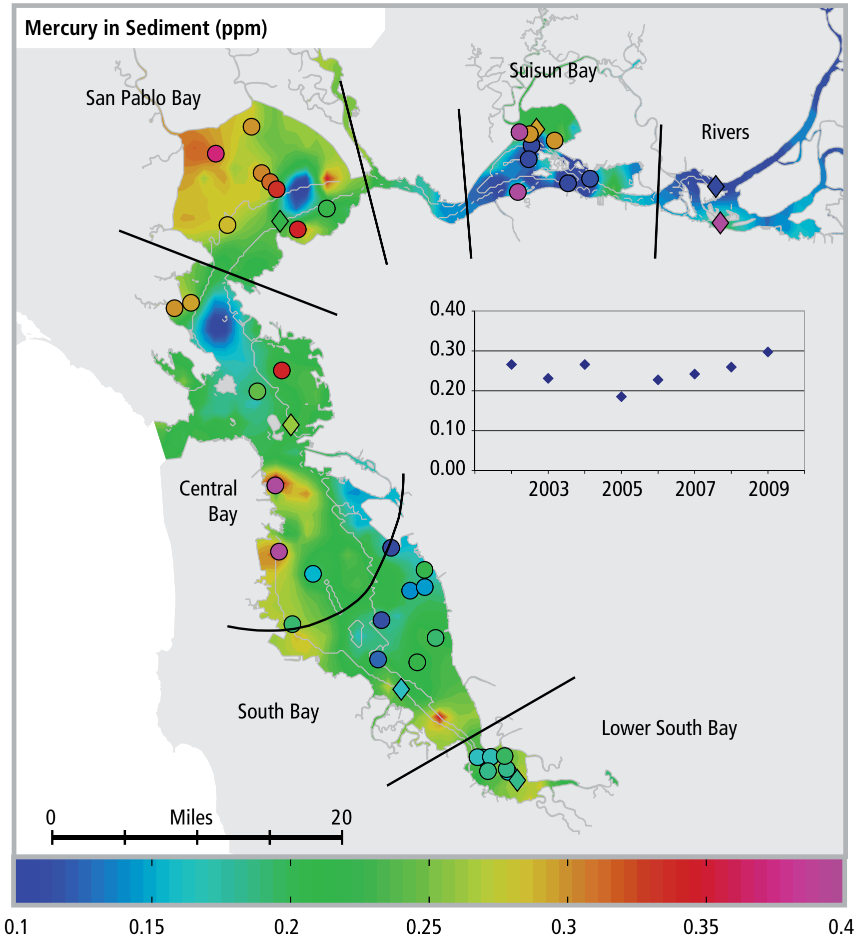
Footnote: Map plot based on 97 RMP data points from 2006-2009. Earlier years not included because a less sensitive method was employed. The maximum concentration was 0.23 ng/L at a site in Lower South Bay in 2009. Trend plot shows annual Bay-wide averages. Data are for total methylmercury. Colored symbols show results for samples collected in 2009. Circles represent random sites. Diamonds represent historic fixed stations.

Water from Lower South Bay had the highest average concentration of methylmercury by far (0.13 ng/L) of any segment from 2006 to 2009. South Bay had the next highest average (0.06 ng/L). Methylmercury typically comprises only about 1% of the total of all forms of mercury in water or sediment, but it is the form that is readily accumulated in the food web and poses a toxicological threat to highly exposed species. Methylmercury has a complex cycle, influenced by many processes that vary in space and time. The RMP measures methylmercury in Bay water and sediment to better understand the sources of the methylmercury that are accumulated by fish and wildlife. No regulatory guideline exists for methylmercury in water. The Bay-wide average in 2009 was 0.03 ng/L. The Bay-wide average for the four-year period was 0.05 ng/L.

↖ Heading toward the Golden Gate sampling station. Photograph by Nicole David.



Footnote: Map plot based on 378 RMP data points over an eight-year period from 2002-2009. The maximum concentration was 6.1 ppb at a site in Central Bay in 2009. Trend plot shows annual Bay-wide averages. Colored symbols show results for samples collected in 2009. Circles represent random sites. Diamonds represent historic fixed stations.



Footnote: Map plot based on 378 RMP data points over an eight-year period from 2002-2009. The maximum concentration was 0.94 ppm in Central Bay in 2009. Trend plot shows annual Bay-wide averages. Colored symbols show results for samples collected in 2009. Circles represent random sites. Diamonds represent historic fixed stations.

Concentrations of methylmercury in sediment south of the Bay Bridge have been consistently higher than those in the northern Estuary. Mercury is converted to methylmercury mainly by bacteria in sediment. Methylmercury production can vary tremendously over small distances and over short time periods, so the figure shown should be viewed as the result of several "snapshots" of Bay conditions at the time of the surveys in the summers of 2002-2009. Long-term average concentrations have been highest in South Bay and Lower South Bay (both averaged 0.70 ppb), and lowest in Suisun Bay (0.20 ppb) and San Pablo Bay (0.27 ppb). The Bay-wide average concentration in 2009 (0.30 ppb) was the lowest observed over the eight-year period, and well below the overall eight-year average (0.50 ppb). No regulatory guideline exists for methylmercury in sediment.

In contrast to methylmercury, long-term average total mercury concentrations in sediment have been highest in San Pablo Bay (0.28 ppm). Average concentrations have been slightly lower in Lower South Bay and Central Bay (both 0.26 ppm) and South Bay (0.22 ppm), and lowest in Suisun Bay (0.17 ppm). The Bay-wide average for the eight-year period was 0.25 ppm. Also in contrast to methylmercury, Bay-wide average concentrations of total mercury in sediment have shown relatively little variability over this period, ranging from 0.19 ppm in 2005 to 0.30 ppm in 2009. Thus the lowest Bay-wide average methylmercury concentration for the eight-year period was observed in 2009, coinciding with the highest average total mercury concentration. Two sites on the western shore of Central Bay had unusually high concentrations in 2009, including the highest in the entire eight-year dataset (0.94 ppm) and one other high value (0.61 ppm).

MERCURY CONTINUED

Contact:
Ben Greenfield, SFEI, ben@sfei.org

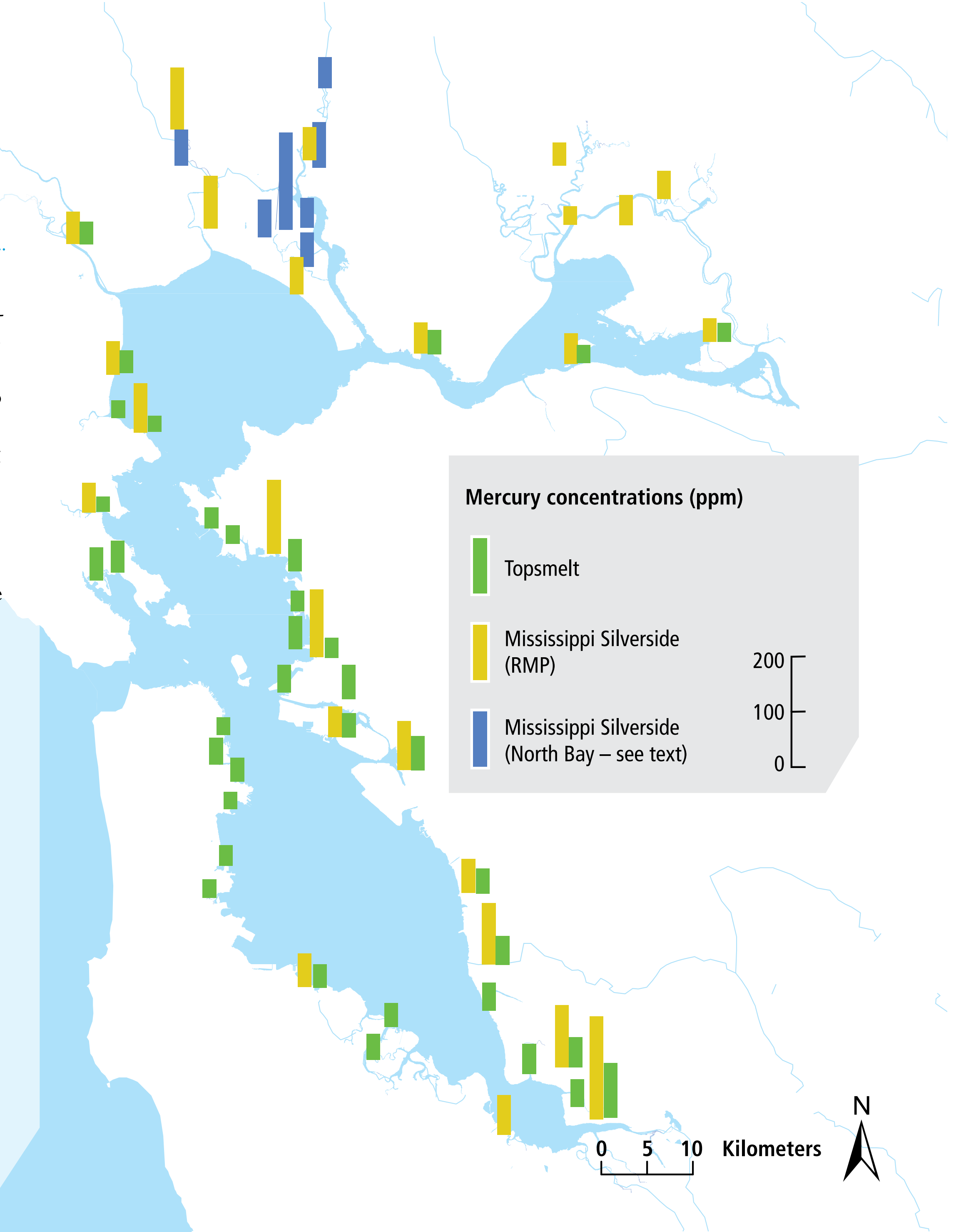
Small Fish Monitoring

Extensive small fish monitoring by the RMP is revealing spatial patterns in food web uptake. The RMP Mercury Strategy is addressing the important gaps that exist in our understanding of methylmercury impairment in the Bay. Gathering information on where and when methylmercury enters the food web has been identified as a top priority. Measuring mercury concentrations in small fish ("biosentinels") is a powerful means for obtaining this information. The young age and restricted ranges of small fish allow the timing and location of their mercury exposure to be pinpointed with a relatively high degree of precision.

In 2008, as part of the Mercury Strategy, the RMP began more extensive small fish monitoring in a concerted effort to determine patterns in food web uptake. This work continued in 2009 and 2010. The annual budget for the three-year study is $150,000, allowing for sampling of approximately 50 sites per year.

Results from the 2009 RMP sampling are now available. Data for two indicator species, Mississippi silverside and topsmelt, are shown. As observed in past years, silverside generally accumulated higher concentrations than topsmelt. Relatively high concentrations in silverside were found at locations in Lower South Bay, the eastern shore of Central Bay, and in the Napa Marsh complex. Relatively high concentrations in topsmelt were observed in Lower South Bay, eastern Central Bay, and Richardson Bay. Concentrations in both species were relatively low in Suisun Bay. Silverside were also sampled using similar methods in 2009 in support of wetland restoration in the Napa Marsh complex in the North Bay (blue bars on map). One of these locations had a concentration rivaling the highest concentration in Lower South Bay.

Results from the three-year study will be interpreted and reported in 2011.



MERCURY CONTINUED

Small Fish: Seasonal Variation

Contact:
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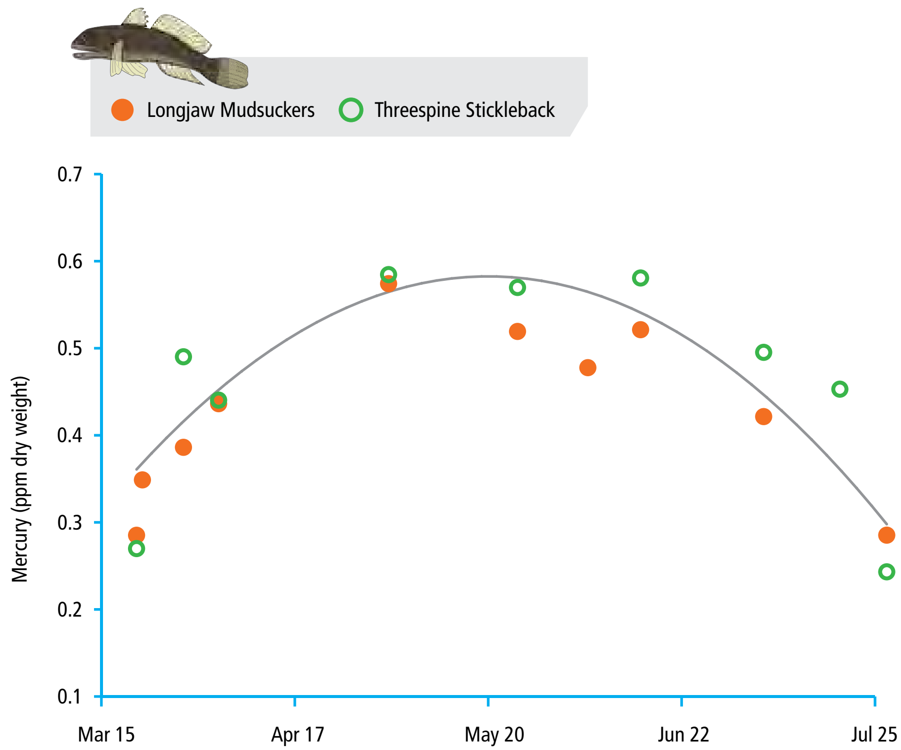
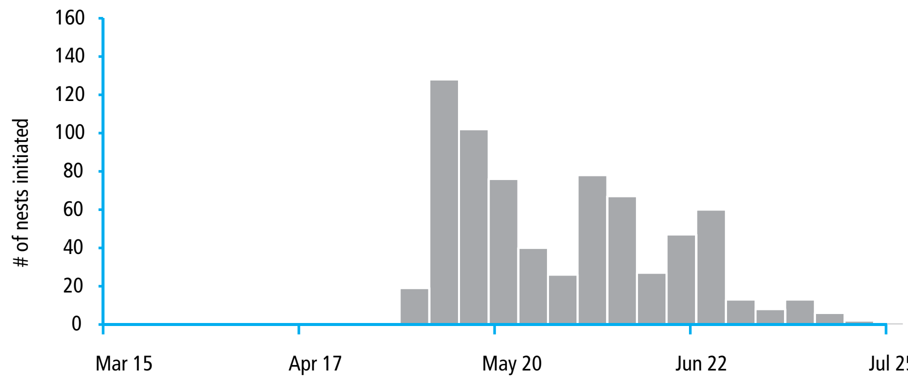
Josh Ackerman, jackerman@usgs.gov

A U.S. Geological Survey study has documented striking seasonal variation in mercury in small fish. This study was part of a broader effort examining mercury accumulation and risks in Bay bird populations. Small fish were examined due to their importance as prey for Forster's Terns, a species at substantial risk from mercury contamination within the Bay (see 2008 Pulse, page 56). The investigators found that longjaw mudsuckers and threespine stickleback were the predominant prey fish, comprising 36% and 25% of the Forster's Tern diet. Mercury concentrations were found to vary substantially over short time spans, increasing by 40% between March and May and then decreasing by 40% between May and July. Importantly, Forster's Terns initiated 68% of nests and 31% of chicks hatched during the period of peak mercury concentrations in prey fish. These results illustrate the importance of short-term variation in small fish mercury concentrations for both monitoring mercury and assessing mercury risks to wildlife.





Reference: C.A. Eagles-Smith and J.T. Ackerman. 2009. Rapid changes in small fish mercury concentrations in estuarine wetlands: implications for wildlife risk and monitoring programs. Environ. Sci. Technol. 43, 8658–8664.

MERCURY CONTINUED

South Baylands Mercury Project

Contact:
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and Jennifer Hunt, jhunt@sfei.org

Restoring tidal marshes may not cause greater mercury problems. Bay Area environmental scientists, managers, and regulators are concerned that tidal marsh restoration may elevate methylmercury concentrations in local wildlife. One way to evaluate this concern is to compare methylmercury in wildlife from the before-restoration and after-restoration habitats. A recent South Bay study used selected wildlife indicator species, or biosentinels, to compare the type of existing habitat (managed historical salt pond) to the restoration endpoint habitat (tidal marsh). Three different biosentinels (longjaw mudsucker, brine fly, and Song Sparrow) were used to represent different parts of the tidal marsh (marsh channel, marsh panne, and marsh plain) among which methylmercury cycling and bioaccumulation might differ. Extensive surveys of these two habitats showed no differences in methylmercury concentrations in wildlife between the existing managed ponds (habitat before restoration) and tidal marsh (habitat after restoration) in either longjaw mudsucker (**FIGURE 1**) or brine fly (not shown). These findings suggest that restoration of managed ponds to tidal marsh may not worsen methylmercury bioaccumulation in local wildlife in the long run.

Biosentinel species must be carefully selected to answer this type of management question, and each biosentinel provides different information. For example, biosentinels for marsh plain (song sparrow), marsh channel (longjaw mudsucker) and subtidal channel (Mississippi silverside) show very different patterns of methylmercury concentrations along the length of Alviso Slough, even though these habitats are very close together (**FIGURE 2A,B,C**). Thus, the marsh biosentinels provide fine-scale information that can be useful to managers for planning when, where, and how to restore tidal marsh.

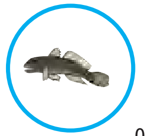


FIGURE 1

Ambient Survey of South Bay

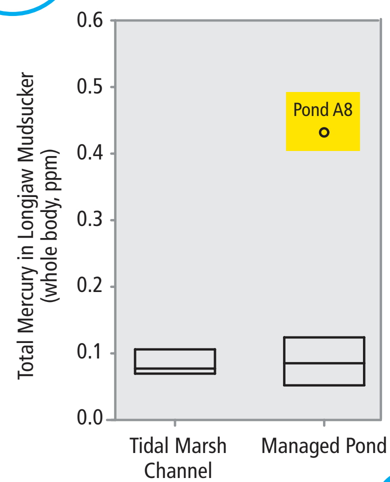
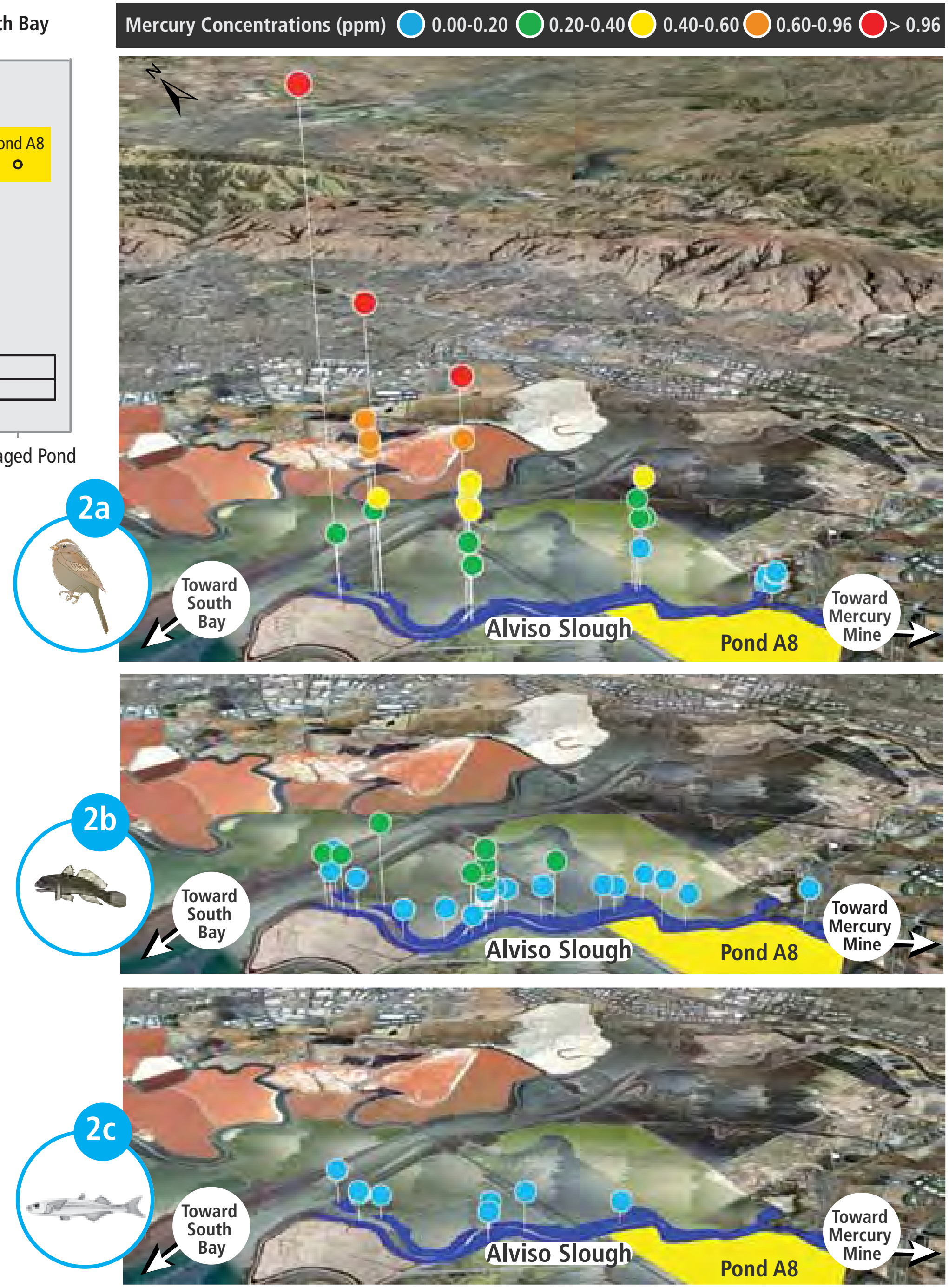


FIGURE 2

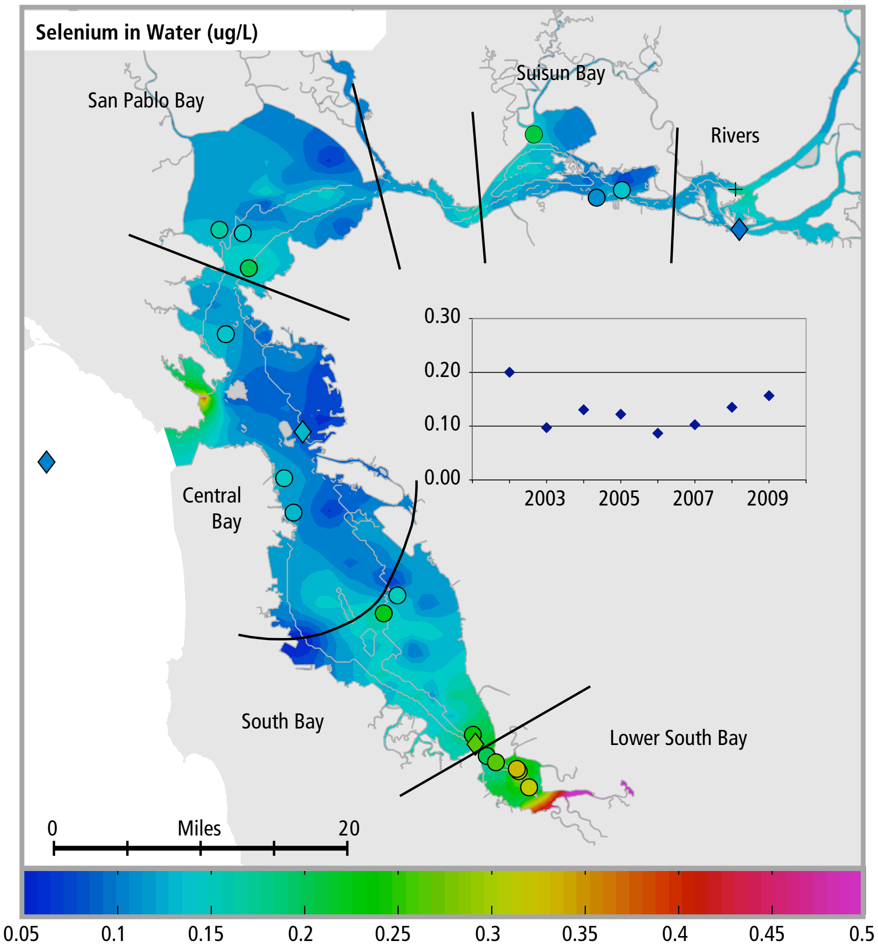


Footnote: Managed ponds are shallow, open-water habitat with little to no tidal flow. These wetlands can be either seasonally or perennially wet and can have various salinities, from close to seawater to extremely salty. Most managed ponds around the edge of San Francisco Bay were originally tidal marshes that were diked and used for salt production (salt ponds) for many decades. Middle line of boxplot indicates median, ends indicate 25th and 75th percentiles.

Mercury concentrations were measured as total mercury in whole body fish and bird blood.

SELENIUM

Selenium contamination is a continuing concern in the Estuary. Selenium accumulates in diving ducks to concentrations that pose a potential health risk to human consumers. Selenium concentrations also pose a threat to wildlife. Recent studies suggest that selenium concentrations may be high enough to cause deformities, growth impairment, and mortality in early life-stages of Sacramento splittail and white sturgeon.



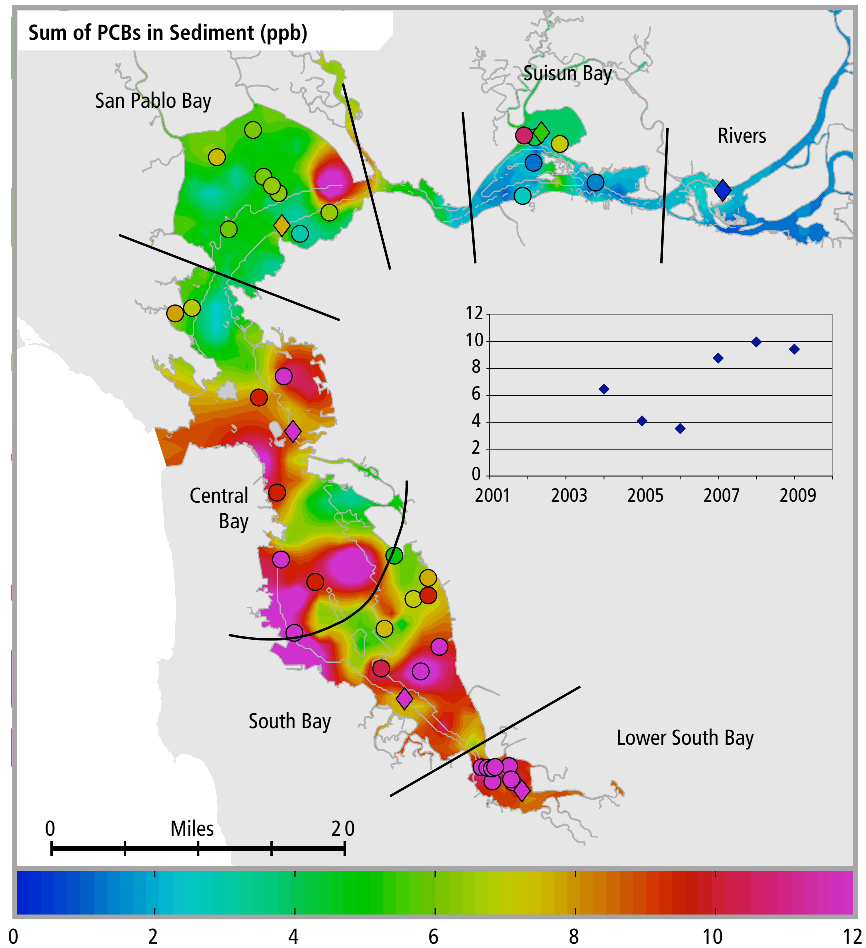
Footnote: Map plot based on 225 RMP data points from 2002-2009. The maximum concentration was 1.2 µg/L at a historical station in the Southern Sloughs in 2002. Trend plot shows annual Bay-wide averages. Data are for total selenium. Colored symbols show results for samples collected in 2009. Circles represent random sites. Diamonds represent historic fixed stations.

Selenium concentrations in water are well below the water quality objective established by the California Toxics Rule (CTR). However, concerns still exist for wildlife exposure as indicated by studies on early life-stages of fish. The highest concentration observed in water from 2002 to 2009 was 1.15 µg/L, much lower than the CTR objective (5 µg/L). The Lower South Bay had a higher average concentration over this period (0.25 µg/L) than the other Bay segments, which had strikingly consistent average concentrations (all other averages were between 0.13 and 0.14 µg/L). The Bay-wide average concentration in 2009 (0.16 µg/L) was slightly higher than the long-term Bay-wide average (0.13 µg/L).

↖ Water sampling gear. Photograph by Nicole David.

PCBs

PCB contamination remains one of the greatest water quality concerns in the Estuary, and PCB cleanup is a primary focus of the Water Board. PCBs are a problem because they accumulate to high concentrations in some Bay fish and pose health risks to consumers of those fish.



Footnote: Map plot based on 282 RMP data points from 2004 – 2009. Data from 2002 and 2003 are not available. The maximum concentration was 30 ppb in South Bay in 2008. Trend plot shows annual Bay-wide averages. Colored symbols show results for samples collected in 2009. Circles represent random sites. Diamonds represent historic fixed stations.

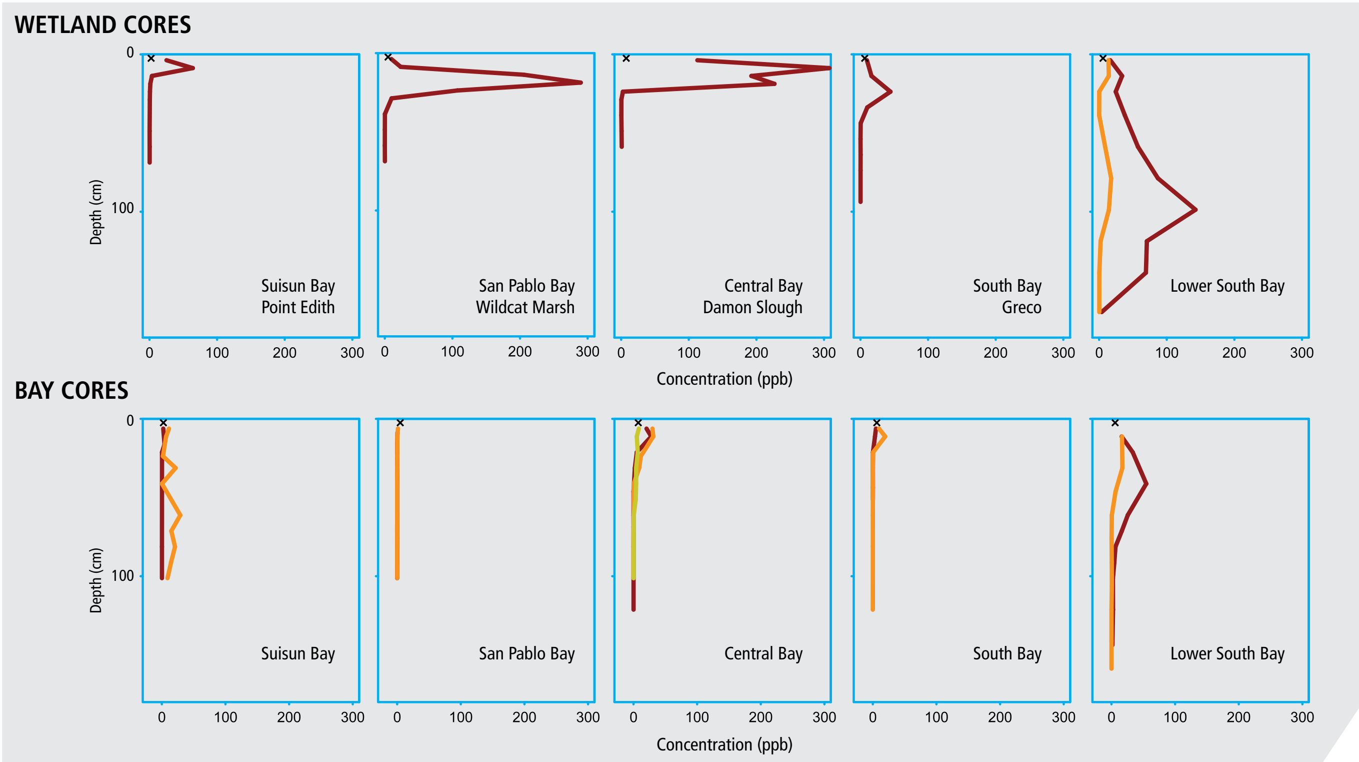
Average PCB concentrations in Bay sediment measured from 2004–2009 were highest in the southern reach of the Estuary: Lower South Bay (9.8 ppb), South Bay (8.2 ppb), and Central Bay (8.7 ppb). Average concentrations were lower in San Pablo Bay (4.7 ppb) and Suisun Bay (2.6 ppb). The Bay-wide average for 2009 was 9.4 ppb, higher than the overall long-term average of 7.0 ppb. Models suggest that sediment PCB concentrations must decline to about 1 ppb for concentrations in sport fish to fall below the threshold of concern for human health. Suisun Bay dipped below this value in 2006 (0.8 ppb), but averaged 4.5 ppb in 2009.

Filtering a water sample. Photograph by Nicole David.

PCBs CONTINUED

PCBs in Sediment Cores

Contact:
Don Yee, SFEI, don@sfei.org



Footnote: x indicates average surface sediment PCB concentrations for each Bay segment based on RMP data, 2002-2006.

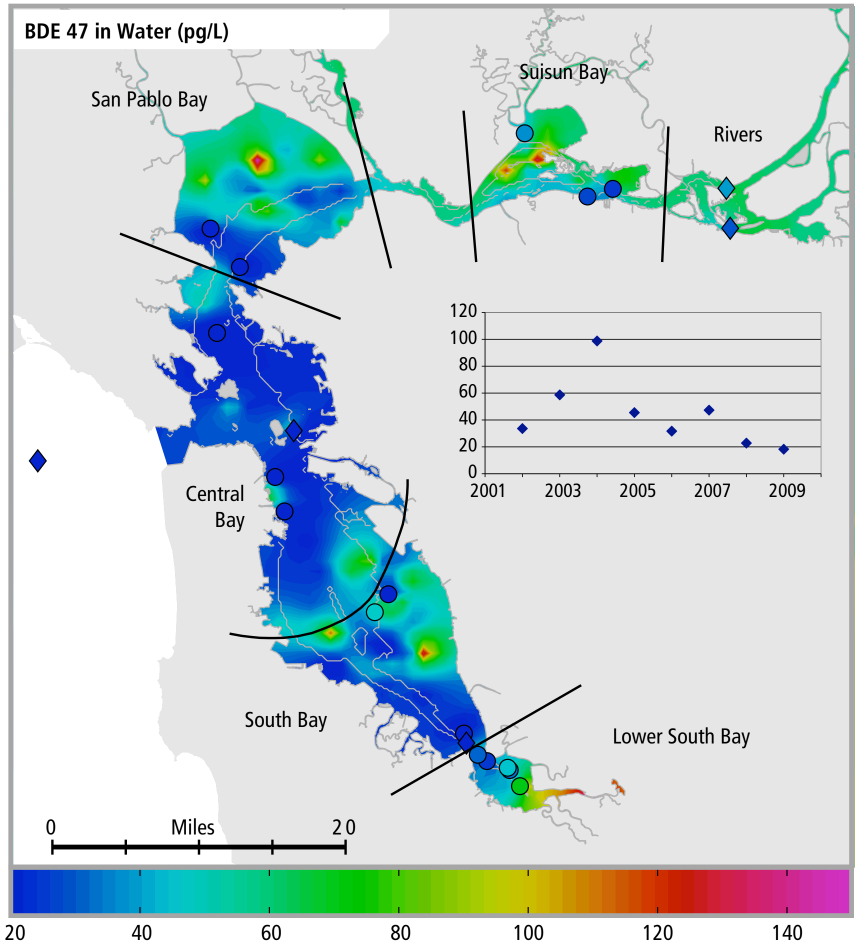
New data on PCB concentrations in sediment cores document substantial improvement since 1960. A recent RMP study examined concentrations of PCBs and other contaminants in sediment cores from tidal marshes and open water areas of the Bay.

Sediment cores from Bay tidal marshes provide a better picture of trends over time because of the consistent deposition and lack of vertical mixing in the marsh environment. The six wetland cores examined in this study generally document drastic decreases in PCB concentrations since the 1960s. In Wildcat Marsh, for example, concentrations dropped from a maximum of 290 ppb at a depth of 19 cm to 10 ppb at a depth of 4 cm, a 97% decrease. In most of these cores, concentrations have fallen to levels comparable to ambient surface sediments in the Bay. Two exceptions to this are Damon Slough (with surface sediments still 14 times higher than ambient) and Point Edith (surface sediments 12 times higher than ambient). Even for Damon Slough and Point Edith, however, concentrations are likely to continue declining rapidly. These wetland cores document a major reduction in loads from local watersheds and concentrations in the Bay.

Sediment cores from the open Bay are more affected by extensive erosion and mixing, so they are less valuable as a record of change over time. However, Bay cores provide information on the subsurface contaminant inventory that is susceptible to erosion, and this information is essential to forecasting the recovery of the Bay. Prior to the new RMP study, the small amount of information available suggested that the subsurface reservoir of contaminants might be large and greatly prolong recovery. The study, however, found this subsurface reservoir to be smaller than expected. Five of the eleven Bay cores had subsurface concentrations that were no higher than the surface concentrations. The other six Bay cores did have higher concentrations at depth, ranging from twelve-fold higher than the surface in a Lower South Bay core to three-fold higher in a South Bay core. Overall, though subsurface concentrations are elevated in some areas of the open Bay, these deposits appear to be less of a concern than previously thought.

PBDES

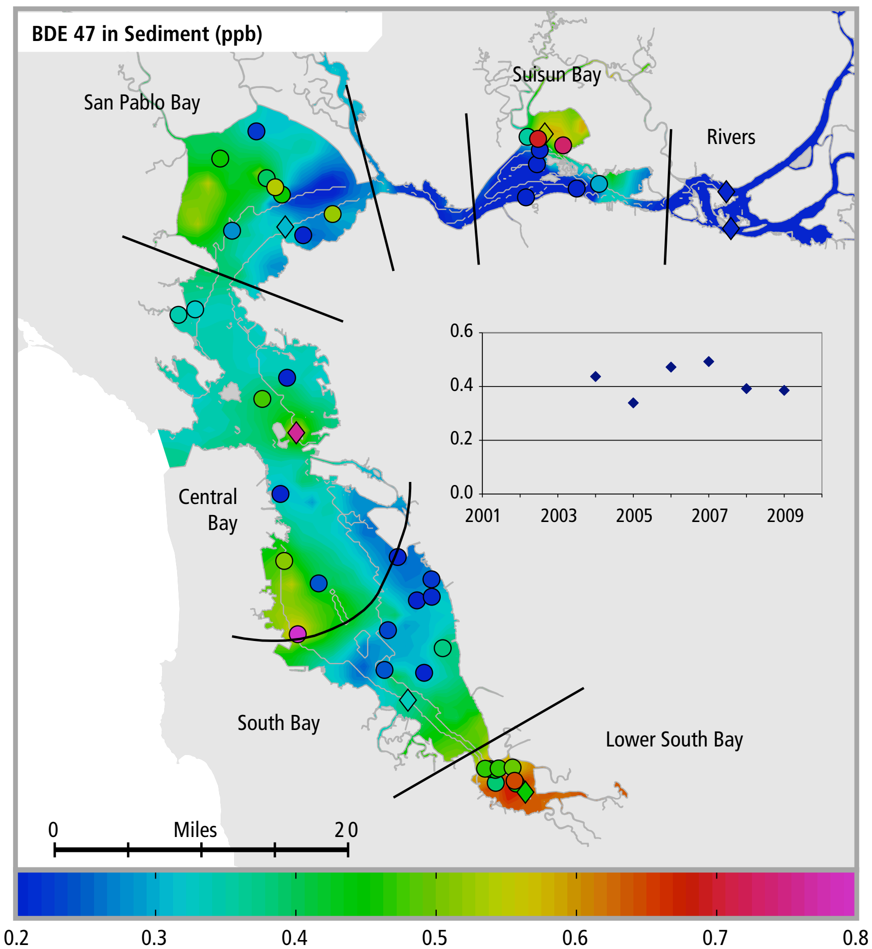
PBDEs, a class of bromine-containing flame retardants that was practically unheard of in the early 1990s, increased rapidly in the Estuary through the 1990s and are now pollutants of concern. The California Legislature has banned the use of two types of PBDE mixtures. Tracking the trends in these chemicals will be extremely important to determine what effect the ban will have and if further management actions are necessary. No regulatory guidelines currently exist for PBDEs.



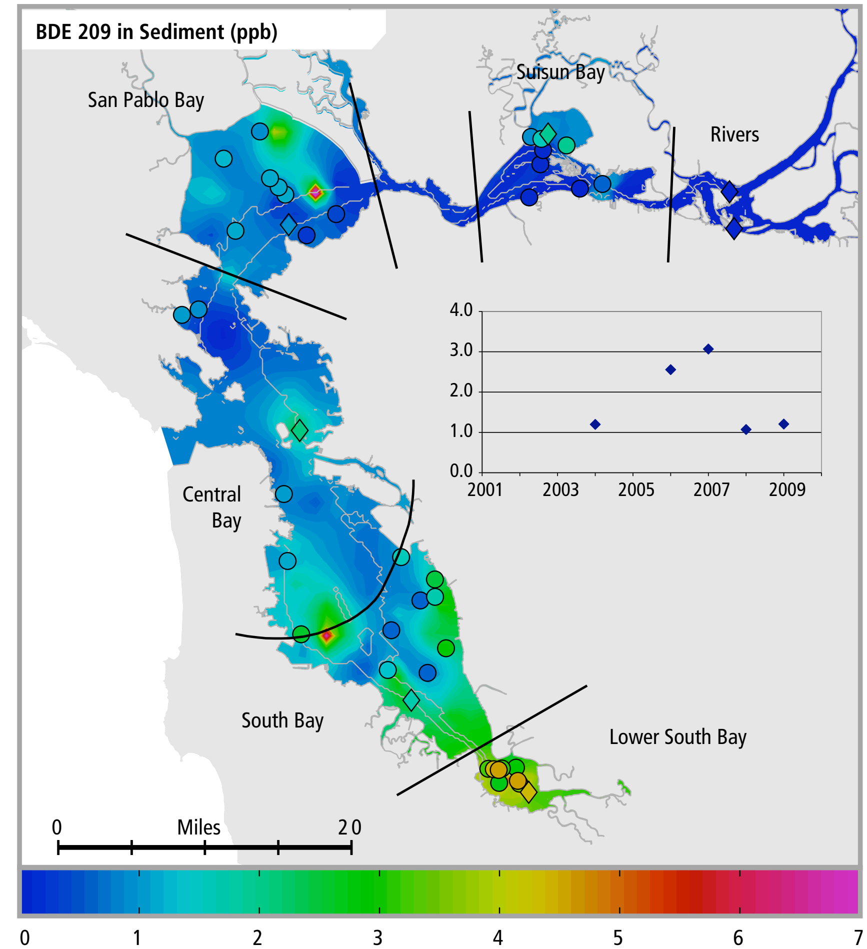
Footnote: BDE 47 shown as an index of total PBDEs. BDE 47 is one of the most abundant PBDEs and was consistently quantified by the lab. Map plot based on 224 RMP data points from 2002-2009. The maximum concentration was 337 pg/L observed in Suisun Bay in 2004. Trend plot shows annual Bay-wide averages. Data are for total BDE 47 in water. Colored symbols show results for samples collected in 2009. Circles represent random sites. Diamonds represent historic fixed stations.

The highest average concentrations of PBDEs in water from 2002–2009 were found in Suisun Bay (76 pg/L). The maximum concentrations of BDE 47 (one of the most abundant PBDEs and an index of PBDEs as a whole), two samples greater than 300 pg/L, were observed at locations in Suisun Bay and San Pablo Bay, both in 2004. The high concentrations in Suisun Bay suggest the presence of PBDE inputs into the northern Estuary. The Bay-wide average concentration for the eight-year period was 47 pg/L. The Bay-wide average for 2009 was the lowest recorded (18 pg/L). The second lowest was 23 pg/L in 2008. The highest Bay-wide average was 99 pg/L in 2004. Whether the low concentrations in 2008 and 2009 represent a declining trend in response to the partial PBDE ban remains to be seen.

↖ Calibrating a water quality meter. Photograph by Nicole David.



Footnote: BDE 47 is one of the most abundant PBDEs and was consistently quantified by the lab. Map plot based on 282 RMP data points from 2004–2009. Data from 2002 are available but were inconsistent with data for the other three years. The maximum concentration, by far, was 3.8 ppb in Lower South Bay in 2005. Trend plot shows annual Bay-wide averages. Colored symbols show results for samples collected in 2009. Circles represent random sites. Diamonds represent historic fixed stations.



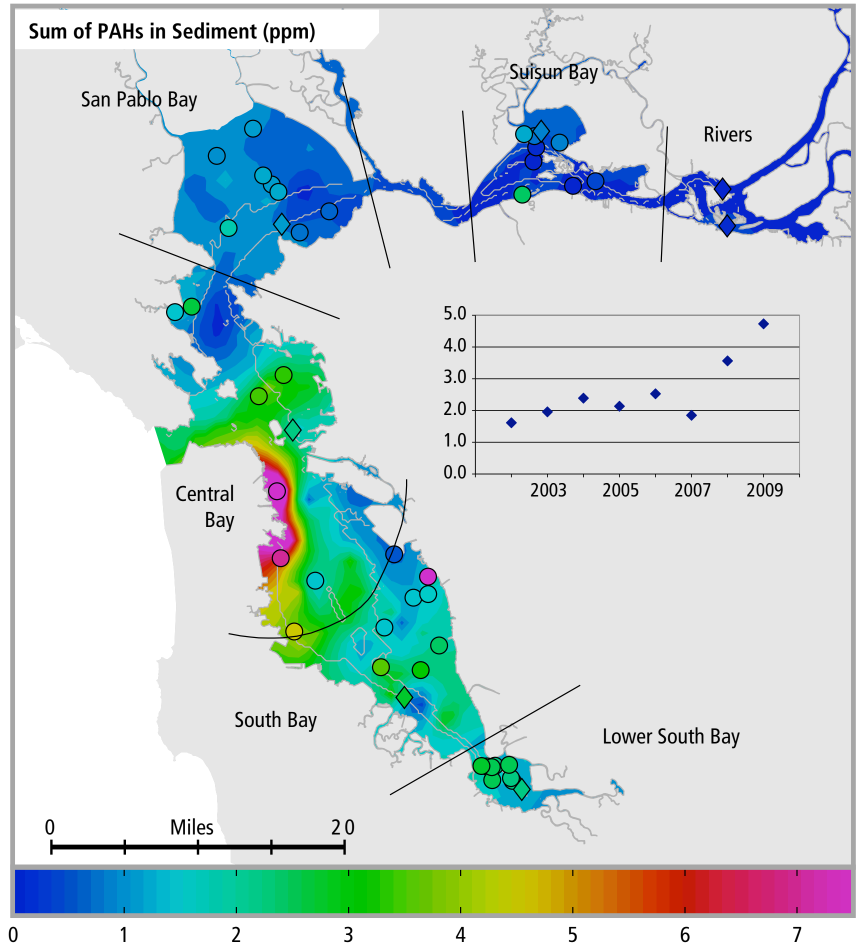
Footnote: BDE 209 shown as an index of the "deca" PBDE mixture. Map plot based on 282 RMP data points from 2004, 2006, 2007, 2008, and 2009. The maximum concentration by far was 52 ppb in San Pablo Bay in 2007 (the next highest concentration was 19 ppb in South Bay in 2006). Trend plot shows annual Bay-wide averages. Colored symbols show results for samples collected in 2009. Circles represent random sites. Diamonds represent historic fixed stations.

In contrast to the results obtained from water monitoring, long-term average concentrations of BDE 47 in sediment from 2004–2009 were highest in Lower South Bay (0.70 ppb). Central Bay had the next highest average (0.45 ppb). The Bay-wide average for 2009 (0.39 ppb) was close to the average for the six-year period of record (0.42 ppb). The Bay-wide average has shown little fluctuation over the six-year period, ranging from a low of 0.34 in 2005 to a high of 0.49 in 2007.

BDE 209 (also known as decabromodiphenyl ether) is important because it represents the one remaining class of PBDEs that can still be used in California. Similar to BDE 47 in sediment, long-term average concentrations of BDE 209 from 2004–2009 were highest in Lower South Bay (4.8 ppb). San Pablo Bay had the next highest average (2.5 ppb). The Bay-wide average concentration of BDE 209 in sediment in 2009 (1.2 ppb) was lower than the long-term average (1.8 ppb), but slightly higher than the Bay-wide average in 2008 (1.1 ppb).

PAHS

PAHs (polycyclic aromatic hydrocarbons) are included on the 303(d) List for several Bay locations. Concentrations tend to be higher near the Bay margins, due to proximity to anthropogenic sources. In addition to historic industrial sources along the Bay margins, increasing population and motor vehicle use in the Bay Area are causes for concern that PAH concentrations could increase over the next 20 years, due to deposition of combustion products from the air directly into the Bay and from the air to roadway runoff and into the Bay via stormwater.



Footnote: Map plot based on 377 RMP data points from 2002-2009. The maximum concentration was 43 ppm at a site on the southwestern Central Bay shoreline in 2009. Eight of the ten highest samples in the eight-year period were from Central Bay. Trend plot shows annual Bay-wide averages. Colored symbols show results for samples collected in 2009. Circles represent random sites. Diamonds represent historic fixed stations.

PAH concentrations in sediment have been highest along the southwestern shoreline of Central Bay. Central Bay had the highest average concentration (4.2 ppm) of any Bay segment from 2002 to 2009. South Bay had the next highest average concentration (2.4 ppm), followed by Lower South Bay (1.8 ppm), San Pablo Bay (1.0 ppm), and Suisun Bay (0.5 ppm). The Bay-wide average in 2009 was 4.7 ppm, the highest for any year in the eight-year period. The next highest annual Bay-wide average was 3.6 ppm in 2008. Each segment also had either its highest or second highest annual average concentration in 2009, with the highest segment average of all measured for Central Bay in 2009 (8.4 ppm). Additional data will be needed to determine whether the high concentrations in 2008 and 2009 are indicative of an increasing trend. The Bay-wide average for the eight-year period was 2.6 ppm.

↖ Oil tanker in the Bay. Photograph by Nicole David.

NONYLPHENOL IN SMALL FISH

Contact:
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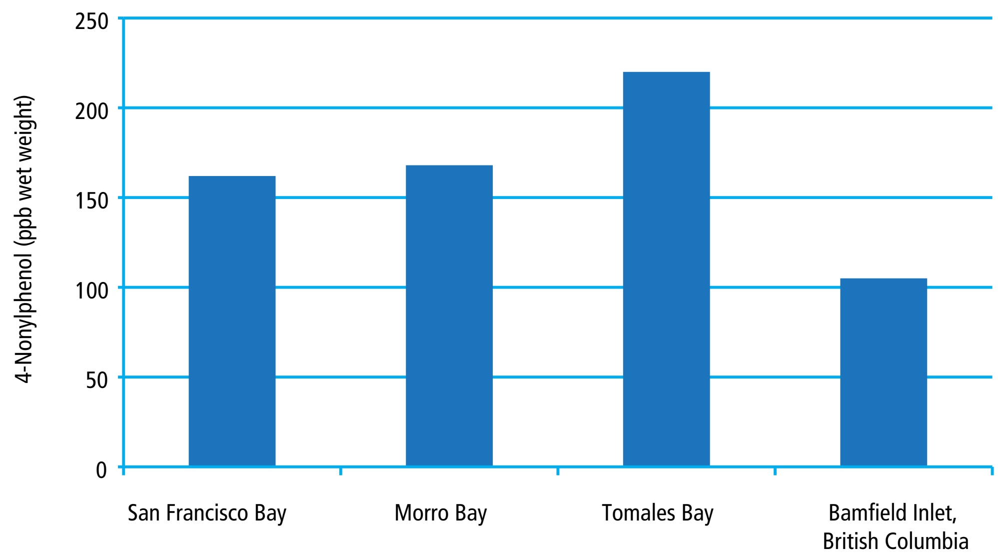
Substantial concentrations of nonylphenol are accumulating in the food webs of west coast estuaries. Alkylphenol ethoxylates (APEs) are surfactants that have been used since the 1940s as detergents and emulsifiers in domestic, industrial, and institutional applications, including paper production, leather and textile processing, and cleaning products. The use of APEs has been restricted in many countries due to concerns about the environmental effects of APE breakdown products, particularly nonylphenol. There are currently no restrictions for the use of APEs in the United States, though some companies, including Procter and Gamble and WalMart, have voluntarily phased out their use in products.



Footnote: Six composite samples of whole fish (arrow gobies from six locations) were collected in San Francisco Bay, 40 in Morro Bay, six in Tomales Bay, and four in Bamfield Inlet. Differences among locations were not statistically signficant, primarily due to the small sample sizes.

Lars Tomanek and his colleagues from California Polytechnic State University, San Luis Obispo have investigated nonylphenol concentrations in Morro Bay and in other west coast estuaries. Nonylphenol is an APE that is hydrophobic, adheres easily to sediment rich in organic content, concentrates in fatty tissues, and persists for decades in low oxygen environments, such as mudflats. Nonylphenol has been found to be an endocrine disruptor in laboratory studies. To date, there have been few studies investigating the bioaccumulation of nonylphenol in marine and estuarine food webs.

Tomanek's team sampled organisms in three California estuaries (including fish collected from San Francisco Bay by the RMP) and one each in Oregon and Canada, and found significant bioaccumulation of nonylphenol in fish regardless of local population density or nearby industries or agriculture. Average concentrations of nonylphenol in arrow gobies were similar in Morro Bay, Tomales Bay, and San Francisco Bay, in spite of the much higher degree of urbanization and industrialization in San Francisco Bay. Concentrations in Bamfield Inlet on Vancouver Island were lower, but the difference was not statistically significant. The risks to aquatic life from these levels of nonylphenol are unknown. The common source of nonylphenol to all these estuaries is likely the discharge of wastewater or septage containing nonylphenol introduced through household products, especially toilet paper.

WATER QUALITY TRENDS AT A GLANCE

Mercury in Sport Fish

Contact:
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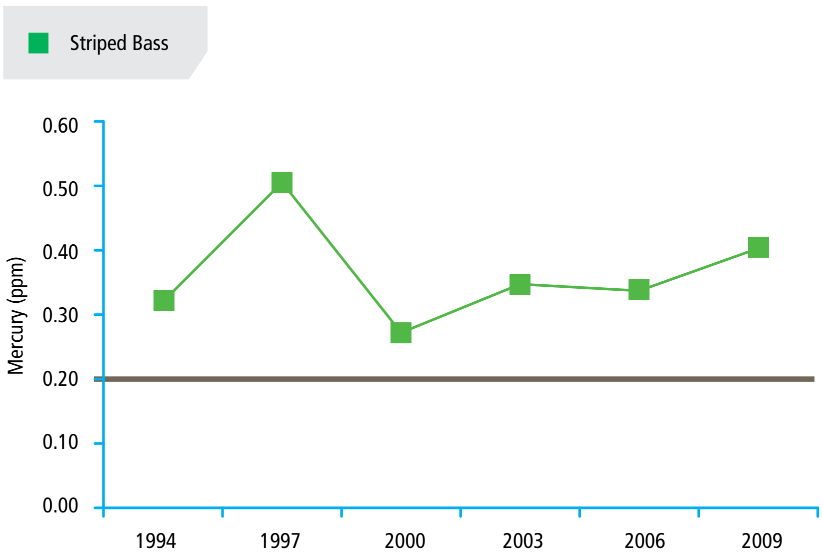

Footnote: Baywide medians. Striped bass: 45–59 cm. Black line indicates TMDL target for sport fish tissue (0.2 ppm). Data from the RMP and Fairey et al. (1997).

Mercury in Sport Fish. Striped bass accumulate relatively high concentrations of mercury and are popular with Bay anglers, making them important indicators of mercury impairment. Mercury concentrations in striped bass show no clear long-term trend but have consistently been higher than the 0.2 ppm TMDL target for sport fish tissue. The most recent Bay-wide average for striped bass was 0.40 ppm in 2009.

PCBs in Sport Fish

Contact:
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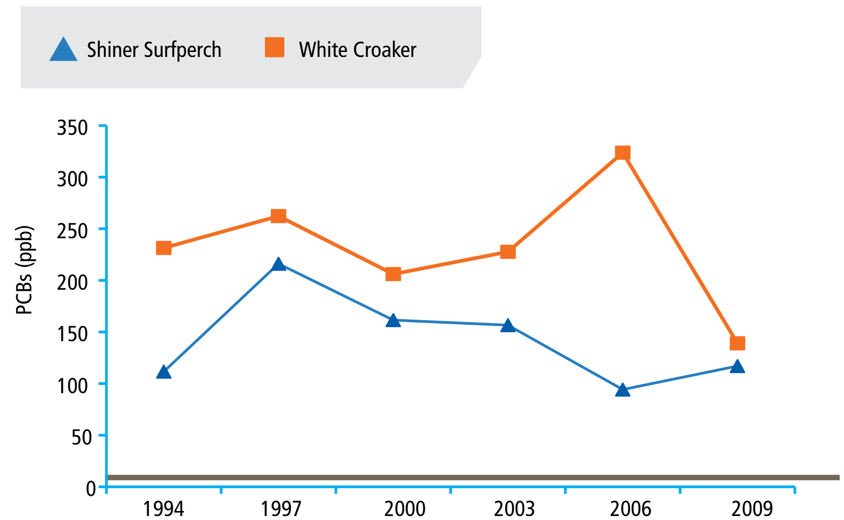

Footnote: Baywide medians. Black line indicates the TMDL target for white croaker (10 ppb). Data from the RMP and Fairey et al. (1997).

PCBs in Sport Fish. White croaker and shiner surfperch are sport fish species that accumulate high concentrations of PCBs and are consequently the key indicators of PCB impairment. Concentrations in white croaker in 2009 were the lowest observed since monitoring began in 1994. This does not, however, signal a decline in PCB contamination in the Bay. The primary reason for this low concentration is the low average fat content of the croaker collected in 2009, which was the lowest for the period of record (2.8% compared to a long-term average of 4.6%). PCBs and other organic contaminants accumulate in fat, so concentrations rise and fall with changing fat content. Concentrations in shiner surfperch were also lower than in most other years. Overall, the data for these two indicator species do not suggest a trend over the past 15 years. PCB concentrations in white croaker have consistently been much higher than the 10 ppb TMDL target for this species.

Total Mercury in Sediment

Contact:
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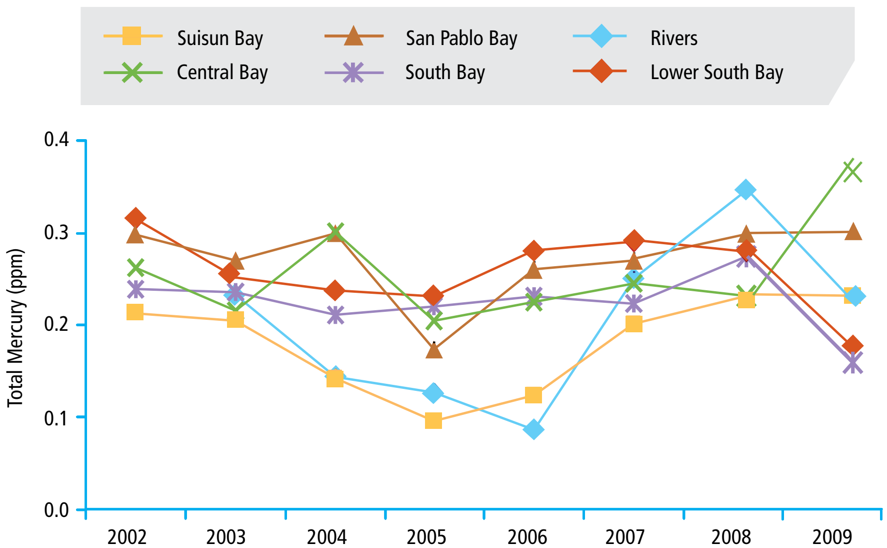
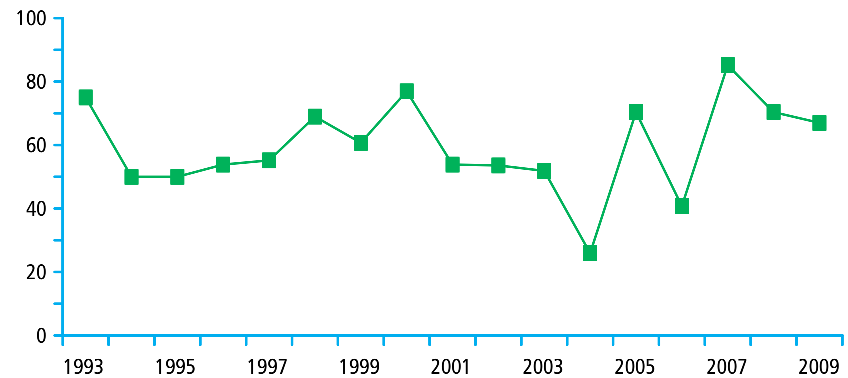


Annual Average Total Mercury in Sediment by Bay Segment. Concentrations of total mercury in sediments in 2009 were lower than the long-term segment averages in South Bay and Lower South Bay, and higher than average in the other segments. The overall Bay-wide average concentration was higher in 2009 than in any other year. In contrast, methylmercury concentrations were at their lowest in 2009 (**page 47**).

Percent Toxic Sediment Samples

Contact:
John Ross, SFEI, john@sfei.org

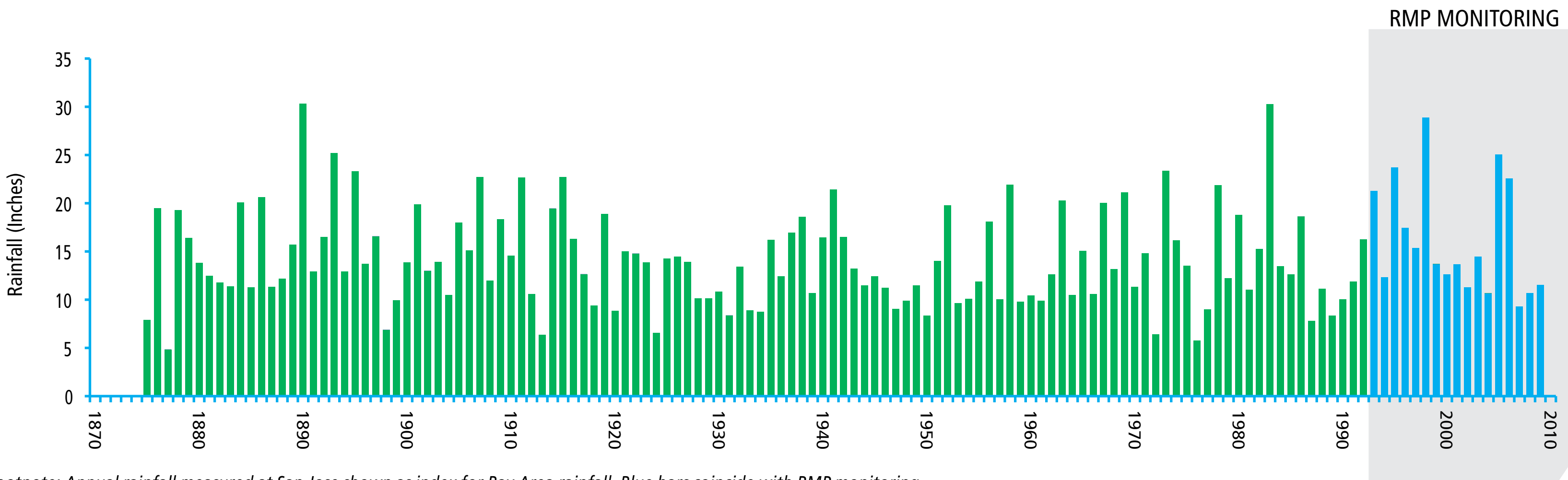


Footnote: Sediment samples are tested using amphipods and mussel larvae.

Percentage of RMP Sediment Samples Causing Toxicity in Lab Tests. The frequent occurrence of toxicity in sediment samples from the Estuary is a major concern. In every year since sampling began in 1993, at least 26% of sediment samples have been determined to be toxic to one or more test species. In 2009, 67% of the samples were found to be toxic to at least one of the two test species. No long-term trend is apparent in this time series.

Annual Rainfall in the Bay Area

Contact:
Lester McKee, SFEI, lester@sfei.org



Footnote: Annual rainfall measured at San Jose shown as index for Bay Area rainfall. Blue bars coincide with RMP monitoring. These data are for climatic years (July 1 to June 30 with the year corresponding to the end date).
Source: Jan Null, Golden Gate Weather Services

Annual Rainfall in the Bay Area. Freshwater flow, as indicated by rainfall, fluctuates widely from year to year, making it more challenging to measure the trends in pollutant inputs and water quality, which are heavily influenced by flow. Records for San Jose date back to 1875. Rainfall at this location in 2009 (11.5 inches) was similar to 2007 and 2008 and lower than the average for the last 40 years (14.9 inches).

Annual Flow from the Guadalupe River

Contact:
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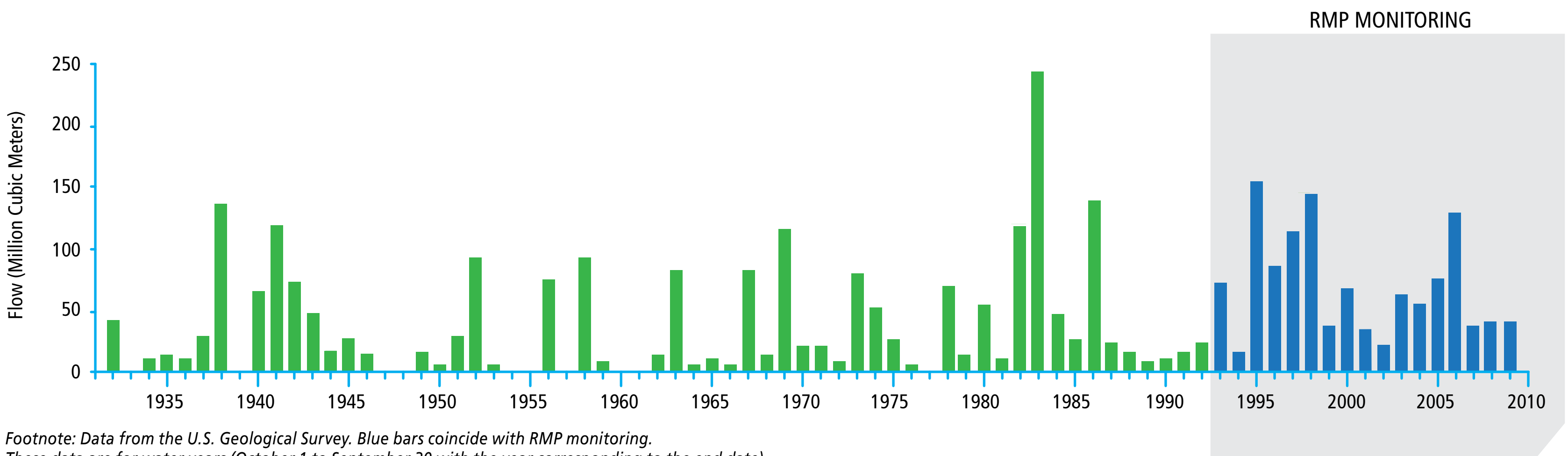

Footnote: Data from the U.S. Geological Survey. Blue bars coincide with RMP monitoring.
These data are for water years (October 1 to September 30 with the year corresponding to the end date).
Source: U.S. Geological Survey.

Annual Flow from the Guadalupe River. Stormwater flows are a primary influence on pollutant loads from local Bay Area watersheds. Flows from the Guadalupe River, a major contributor of mercury to the Bay, were relatively low in 2007, 2008, and 2009 (36, 41, and 42 million cubic meters, respectively) compared to the average for the last 40 years (54 million cubic meters). Year to year variation in flow from the Guadalupe watershed is a rough index of variation in flows from other local watersheds.

Mercury from the Guadalupe River

Contact:
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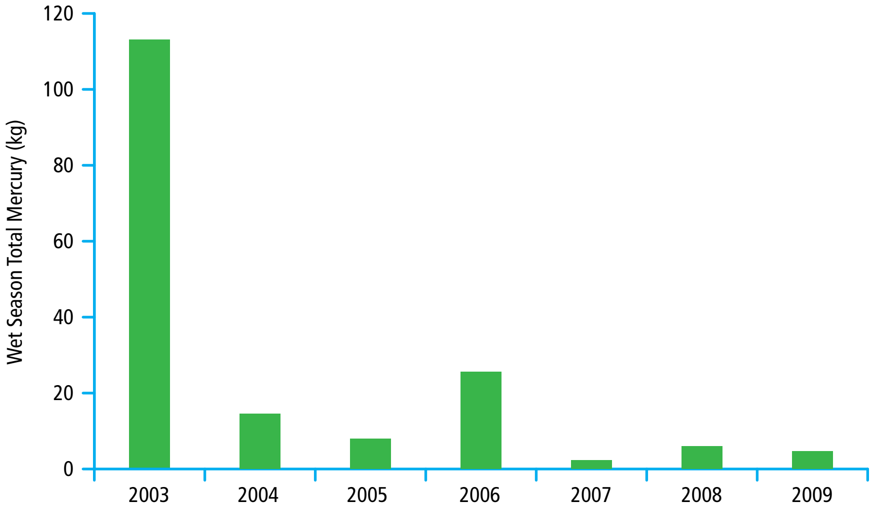

Footnote: Total loads for each water year (Oct 1–Sep 30). Additional matching funds for this RMP study were provided by the CEP, USACE, SCVWD, and SCVURPPP.

Annual Loads of Mercury from the Guadalupe River. The Guadalupe River is a significant pathway for transport of mercury and other pollutants into the Bay, and the first small tributary to the Bay subjected to a rigorous evaluation of loads. Loads fluctuate from year to year due to variation in rainfall intensity, water flow, and other factors. For example, even though flow during 2006 was relatively high, it was a year of relatively low rainfall intensity; consequently there were many small-magnitude floods that did not transport a large amount of mercury. The load estimated for 2009 was 5 kg, the second lowest recorded since monitoring began in 2003. The year-to-year fluctuations are thought to be driven by climatic variation and not indicative of a long-term trend.

Mercury from the Delta

Contact:
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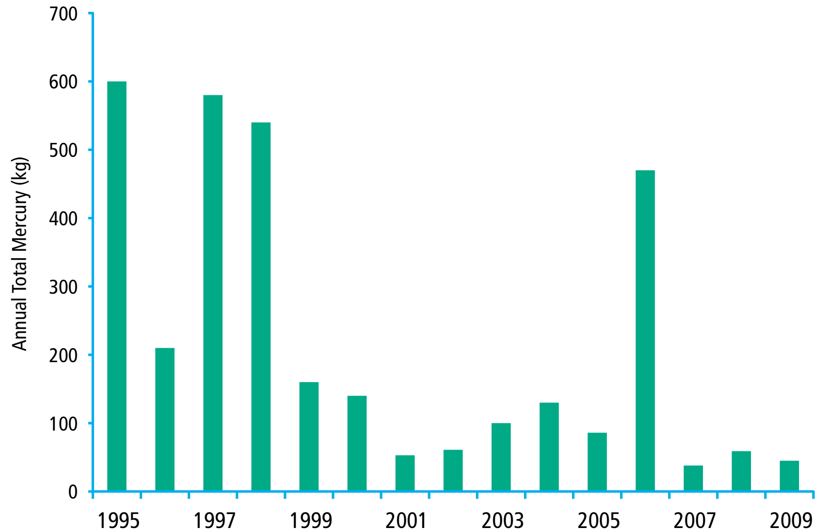

Footnote: Total loads for each water year (Oct 1–Sep 30). Loads from 2002–2006 are based on field data. Loads for earlier and later years are estimated from relationships observed between suspended sediment and mercury in 2002–2006.

Annual Loads of Mercury from the Delta. Delta outflow carries significant loads of mercury and other pollutants from the vast Central Valley watershed into the Bay. RMP studies allow estimation of loads from 1995 to the present. Loads of many pollutants are especially large in years with high flows. Sampling conducted during the high flows of January 2006 helped to refine the annual estimates, which had previously been significantly underestimated for large flood events. The annual load in 2009 (45 kg) was the second lowest estimated for the 15-year period. This low load corresponded to the third lowest flow over this timeframe.

Bay Area Population

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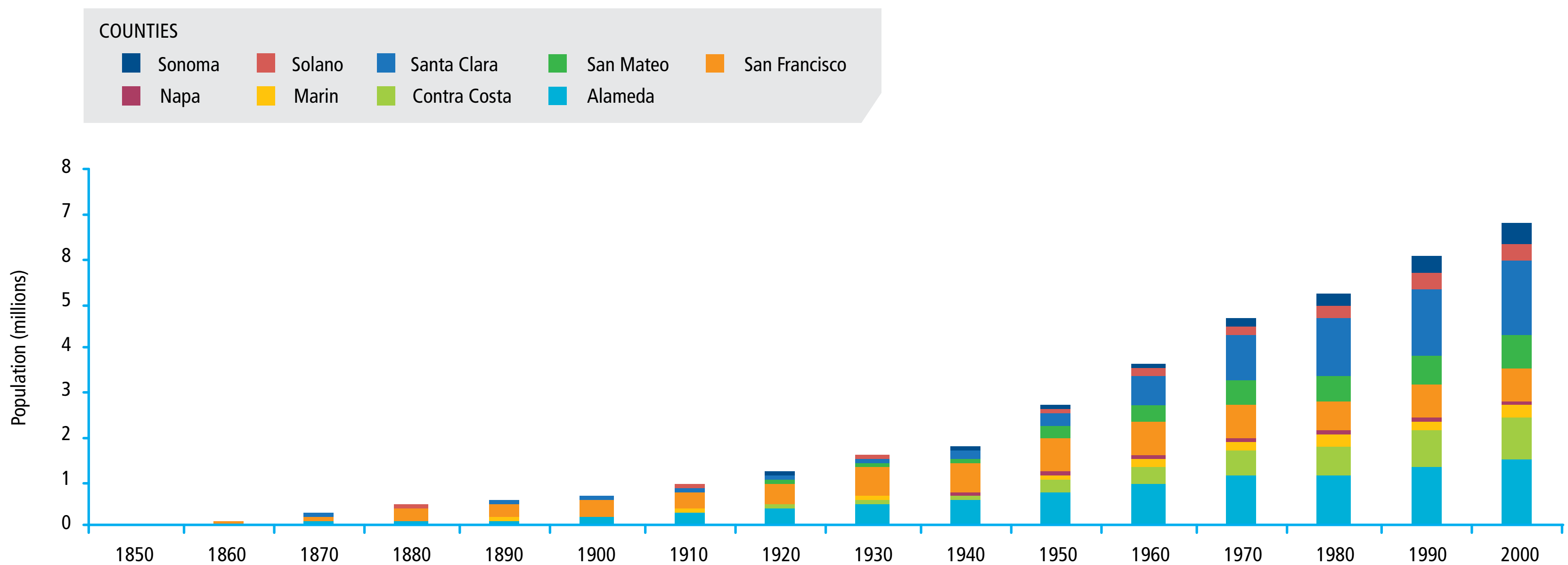
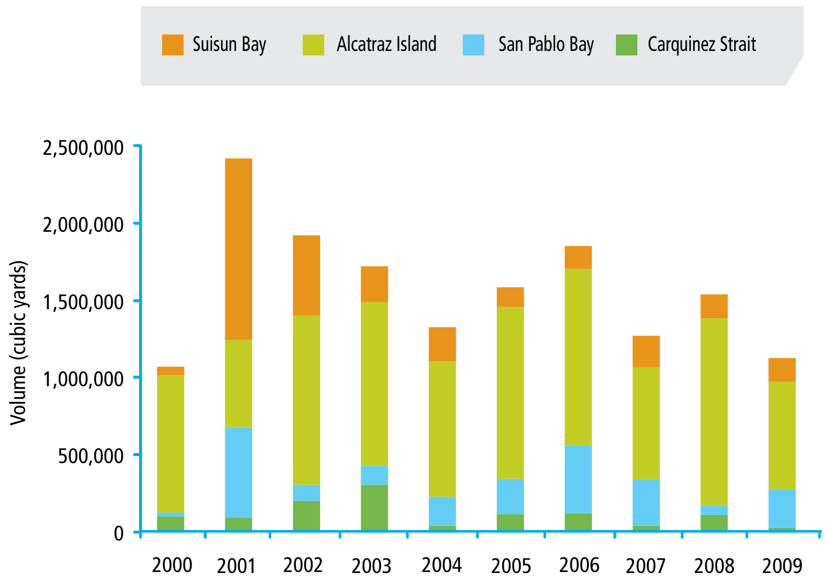


Footnote: Data from the Association of Bay Area Governments and U.S. Census Bureau. 2009 estimate from http://factfinder.census.gov/servlet/SAFFPopulation?_submenuId=population_0&_sse=on.

Bay Area Population. The large and growing human population of the Bay Area places increasing pressure on Bay water quality through expanding urbanization, vehicle usage, and other mechanisms. The population of the Bay Area reached 6.8 million in 2000, is estimated to be 7.1 million in 2009, and is predicted to grow to 7.8 million by 2020.

In-Bay Disposal of Dredged Material

Contact:
Rachel Allen, SFEI, rachel@sfei.org



Footnote: Data from the U.S. Army Corps of Engineers.

Annual Volume of Dredged Material Deposited at In-Bay Aquatic Disposal Sites. Dredged material disposal is one of the pathways for pollutant redistribution within the Bay. In 2009, 1.1 million cubic yards of dredged material were deposited at the four disposal sites in the Bay. Most of this amount (62%) was disposed of at the Alcatraz site. Dredged material management agencies plan to limit in-Bay disposal to 1.5 million cubic yards per year by 2012. The annual volume has been below this target in four of the last ten years.

Acres Restored to Tidal Action

Contact:
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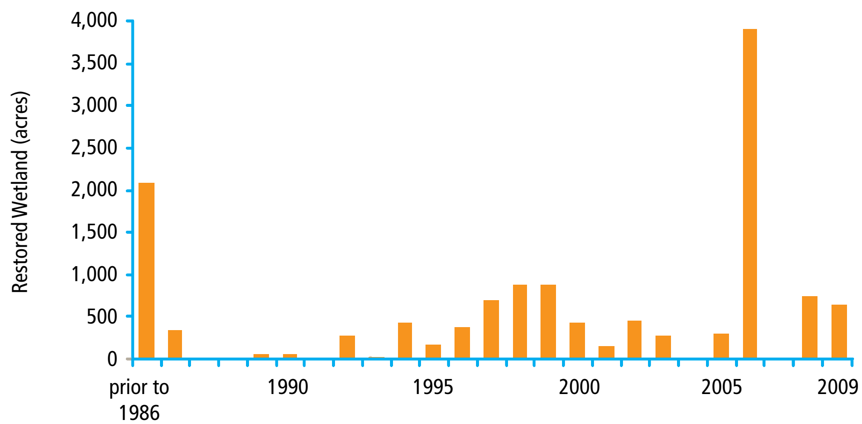

Footnote: Data from the California Wetlands Portal (www.californiawetlands.net/tracker/).

Acres of Salt Pond or Other Habitat Opened to Tidal Action. San Francisco Bay is home to the most ambitious tidal wetland restoration project ever attempted on the west coast of North America, the South Bay Salt Pond Restoration Project, which plans to restore 16,500 acres of San Francisco Bay salt ponds to tidal marsh. Several other major tidal wetland restoration projects are also underway. These projects could have a significant influence on Bay water quality, with the potential for increased mercury in the food web a particular concern. SFEI and others are conducting studies to assist restoration managers in developing methods to limit the production of methylmercury. In 2009, 643 acres were opened to tidal action.

Chlorophyll in the Bay

Contact:
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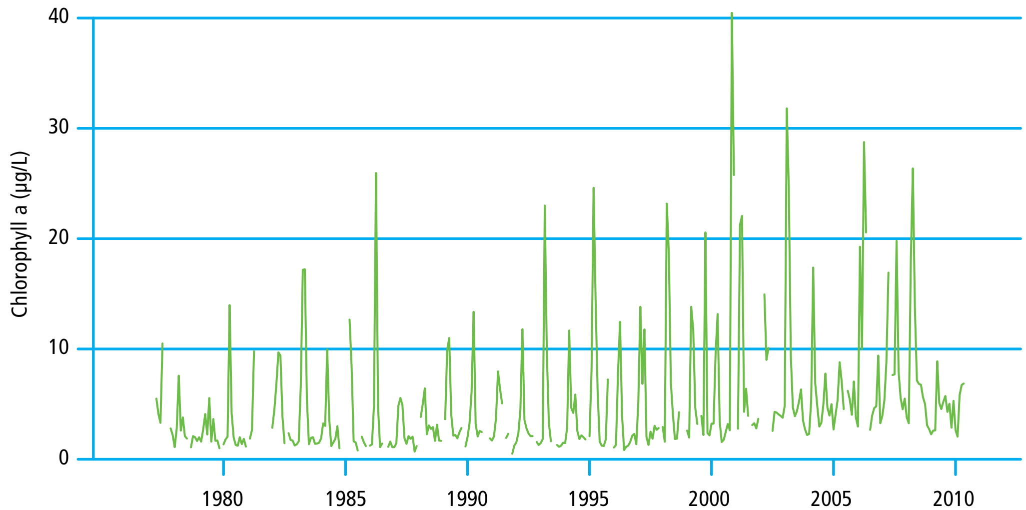

Footnotes: Chlorophyll concentrations are an index of the abundance of phytoplankton in the Bay. Data for USGS Station 27. Median of all measurements shallower than 3 meters depth. Data from the U.S. Geological Survey (http://sfbay.wr.usgs.gov/access/wqdata/).

Graph prepared by Alan Jassby, U.C. Davis (adjassby@ucdavis.edu)

Reference: Cloern, J.E., A.D. Jassby, J.K. Thompson, and K.A. Hieb. 2007. A cold phase of the East Pacific triggers new phytoplankton blooms in San Francisco Bay. Proceedings of the National Academy of Sciences (104): 18561–18565.

Annual and Seasonal Trends in Phytoplankton Biomass. Since the late 1990s, significant changes in phytoplankton population dynamics in San Pablo, Central, and South bays have occurred; these include larger spring blooms, blooms during other seasons, and a progressive increase in the "baseline" or annual minimum chlorophyll. As an example, this series of monthly chlorophyll concentrations from one monitoring location shows the increase in baseline chlorophyll (the minimum value each year), and occurrences of autumn/winter blooms in the past decade. According to an article published in 2007 (Cloern et al. 2007), the increase in phytoplankton biomass and new blooms are thought to be caused by a cascade of effects driven by increased upwelling in the coastal ocean, leading to strong recruitment of flatfish and crustaceans into the Bay. These species are bivalve predators that appear to have reduced the populations of bivalves that consume phytoplankton. Increasing water clarity may also be contributing to the increased phytoplankton biomass. In the most recent sampling changes in phytoplankton dynamics appear to be continuing - the baseline chlorophyll remained high, but there were no prominent blooms. The reasons for the lack of blooms are unclear.

FEATURE ARTICLES

68 THE SURFACE WATER AMBIENT MONITORING PROGRAM: A VIEW FROM THE SWAMP

80 TRIBUTARY LOADS: AN UPDATE ON LARGE AND SMALL WATERSHEDS

↑ Views of San Leandro Creek. Photographs by Linda and Charles Wanczyk.

THE SURFACE WATER AMBIENT MONITORING PROGRAM: A VIEW FROM THE SWAMP

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Walker Creek, Marin County. Photograph by Peter Otis.

Highlights

- The Surface Water Ambient Monitoring Program (SWAMP) is a statewide water quality monitoring program that provides data needed to effectively manage California's water resources
- A regional component of SWAMP in the Bay Area has generated information on stream health and fish contamination resulting in 50 existing or proposed 303(d) listings for impaired streams and lakes
- Two statewide SWAMP studies are also generating valuable information for the Bay region: the Healthy Streams Initiative and surveys of contaminants in fish
- Statewide standards for "SWAMP comparability" are ensuring that monitoring and regulatory programs generate consistent, high quality data
- SWAMP findings are available to the public through the state's new "My Water Quality" website
- Through SWAMP and related efforts, the state has made great strides in improving the efficiency and effectiveness of water quality and habitat quality monitoring, and in providing broader access to this information

California's SWAMP

Since 1993 the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) has provided a regional perspective on water quality in San Francisco Bay. Until recently, although individual groups and municipalities had conducted water quality monitoring in the streams that feed into the Bay, there was no comparable regional or statewide effort to provide this perspective in our watersheds. The Surface Water Ambient Monitoring Program (SWAMP), introduced by the State Water Resources Control Board (State Water Board) and Regional Water Boards in 2001, has addressed this need.

SWAMP is a statewide effort that provides the scientifically sound data needed to effectively manage California's water resources. SWAMP's goal is to monitor and assess water quality to determine whether the state is meeting water quality standards and protecting beneficial uses. SWAMP accomplishes this goal through four primary activities. The Program:

- conducts statewide and regional monitoring in two focus areas: stream health and bioaccumulation of contaminants;
- creates a common framework, "SWAMP comparability," that allows for the coordination of statewide monitoring by offering a uniform and objective approach to monitoring, sampling and analysis, quality assurance, and centralized data management;
- collaborates with other agencies in the state that monitor water quality so that efforts are comprehensive, integrated, non-duplicative, and appropriately funded; and
- provides technical expertise to project participants and stakeholders.

The nine Regional Water Boards manage regional SWAMP monitoring programs designed to address management issues specific to each region. The San Francisco Bay Regional Water Quality Control Board manages a significant regional SWAMP effort in the Bay Area. SWAMP also has statewide components that conduct surveys across all of the regions. The regional and statewide efforts are coordinated and complementary. Both the regional and statewide components have generated a wealth of useful water quality data for Bay Area water bodies.

Monitoring in the Regional SWAMP

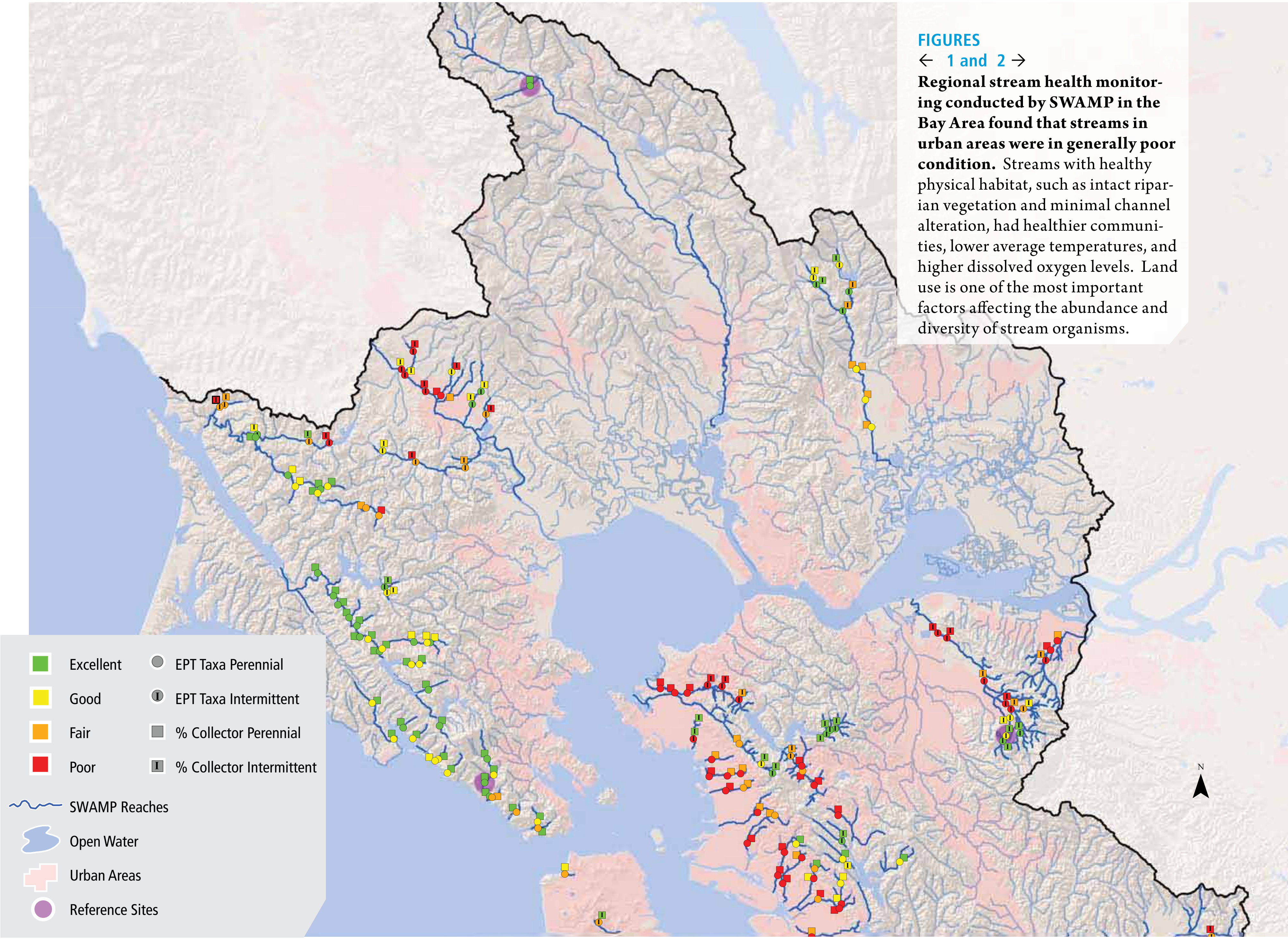
Regional Stream Health Monitoring

Initial Surveys: 2001-2006

Starting in 2000 and for the next five years SWAMP performed regional monitoring of condition in 37 Bay Area streams. Benthic macroinvertebrate (sediment-dwelling organism) surveys ("bioassessments") and physical habitat assessments were conducted, as well as continuous monitoring of water temperature, dissolved oxygen, pH, and conductivity. Contaminants and toxicity in the water were measured during winter, spring, and summer. Sediment was sampled in the spring and analyzed for chemistry and toxicity. Trash was also monitored in 14 creeks.

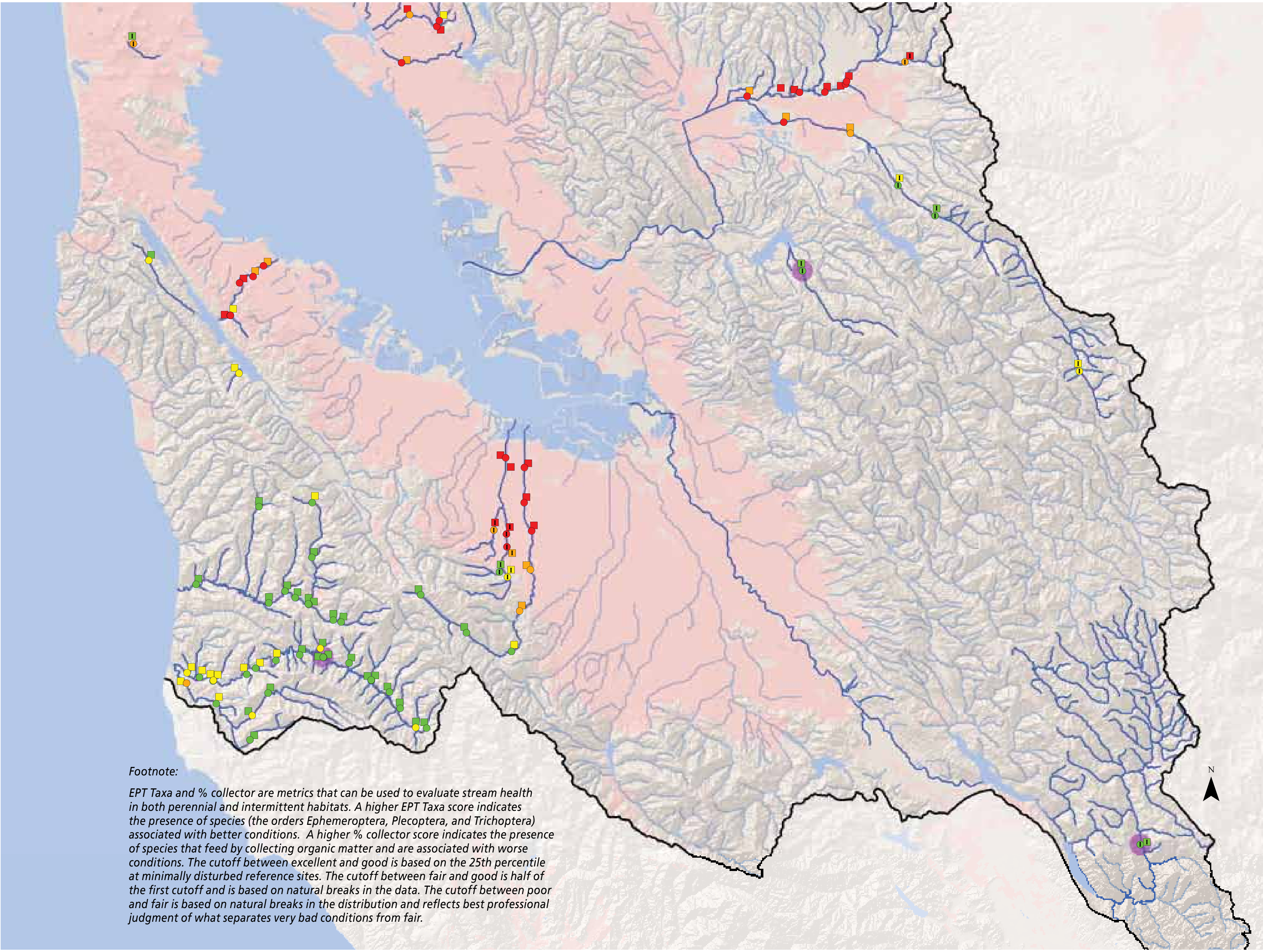
This regional stream health monitoring supported several general conclusions.

- Land use is one of the most important factors affecting the abundance and diversity of benthic organisms. In general, benthic communities in urban areas were in poor condition, while communities in non-urban areas were in good condition (**FIGURES 1** and **2**).
- Streams with healthy physical habitat (intact riparian habitat and minimal channel alteration) had healthier benthic communities, lower average temperatures, and higher dissolved oxygen.
- Nitrate and phosphorus are constituents in fertilizers and animal wastes that can stimulate excessive growth of algae in streams and other aquatic ecosystems. Nitrate and phosphorus concentrations were highest and most variable in streams draining urban areas, although some streams located upstream of urban areas, even at reference sites, had high nutrient concentrations (**FIGURE 3**).
- In general, concentrations of chemical contaminants were low and toxicity was moderate. Concentrations of contaminants were higher in dry weather than other seasons probably due to lack of dilution. However, stormwater was not monitored in this ambient monitoring program.
- Based on application of a SWAMP rapid trash assessment method in 14 Bay Area watersheds, all watersheds had high levels of trash, with sites lower in the watershed having the highest levels. Trash source hotspots near stream channels, usually associated with parks, schools, roads, or poorly kept commercial facilities, contributed a significant portion of trash that was deposited or carried during storms to lower watershed sites.



FIGURES
← 1 and 2 →

Regional stream health monitoring conducted by SWAMP in the Bay Area found that streams in urban areas were in generally poor condition. Streams with healthy physical habitat, such as intact riparian vegetation and minimal channel alteration, had healthier communities, lower average temperatures, and higher dissolved oxygen levels. Land use is one of the most important factors affecting the abundance and diversity of stream organisms.



Footnote:

EPT Taxa and % collector are metrics that can be used to evaluate stream health in both perennial and intermittent habitats. A higher EPT Taxa score indicates the presence of species (the orders Ephemeroptera, Plecoptera, and Trichoptera) associated with better conditions. A higher % collector score indicates the presence of species that feed by collecting organic matter and are associated with worse conditions. The cutoff between excellent and good is based on the 25th percentile at minimally disturbed reference sites. The cutoff between fair and good is half of the first cutoff and is based on natural breaks in the data. The cutoff between poor and fair is based on natural breaks in the distribution and reflects best professional judgment of what separates very bad conditions from fair.

- In general, poor physical habitat, elevated nutrients, elevated temperatures, and low dissolved oxygen seemed to be the stressors most affecting stream biota during ambient (non-storm) flow conditions.

Based on this monitoring, a series of recommendations were developed for monitoring ambient conditions in Bay Area streams.

- A reference site study should be conducted to determine unimpacted conditions for benthic bioassessment indicators and nutrients in this region and to assess relationships among nutrient concentrations, algae biomass, temperature, light, and dissolved oxygen. Such a study would enhance our ability to recognize sites that do have impacts.
- Bioassessment, coupled with physical habitat assessment, is the most useful indicator to assess stream health since it is a direct measure of the health of organisms that inhabit the stream. In addition, bioassessments indicate the cumulative impacts of multiple stressors and integrate these impacts over time. An Index of Biological Integrity (an index used to interpret benthic community survey data) should be developed for the Bay Area to better assess data and to protect the health of aquatic life in streams.
- It is important to monitor nutrients and chlorophyll (an indicator of algal growth), and to continuously monitor temperature and dissolved oxygen to evaluate the stressors that may most impact aquatic life in streams.
- Toxicity should be monitored in streams with urban, industrial, or agricultural land uses.
- Projects to restore the physical integrity of streams and to keep fine-grained sediment, trash, nutrients, and other contaminants out of streams should be encouraged.
- A regional watershed monitoring coalition should be formed to provide a more comprehensive and coordinated regional approach to watershed monitoring.

Monitoring requirements for the Municipal Regional Stormwater Permit (MRP – page 8) were based on the results of these five years of regional SWAMP stream monitoring. Descriptions of these studies and results for specific streams can be found in SWAMP reports at: http://www.waterboards.ca.gov/sanfranciscobay/water_quality.shtml.

Reference Site Monitoring and Improved Nutrient Objectives

Starting in 2008 and through 2010, the regional SWAMP implemented the recommendation for reference site monitoring by sampling in Coyote, Indian, Mt. Diablo, Ritchie, Redwood, and Pescadero creeks. These reference sites were chosen to represent different ecoregions, intermittent and perennial streams, and large and small stream sizes. The purpose of this monitoring is to determine

↖ Bioassessment sampling in Coyote Creek. Photograph by Karissa Anderson.

reference conditions in this region for bioassessment indicators (benthic macroinvertebrates and algae) and nutrients, and to assess relationships between nutrient concentrations, algal biomass, temperature, light, and dissolved oxygen.

USEPA has developed nutrient criteria based on reference conditions that apply to the Bay Area (USEPA 2000). Most samples collected from April-October at sites in the region exceeded these criteria. Of 249 samples, 70% exceeded the 0.155 mg/L nitrate criterion, and 93% exceeded the 30 ug/L total phosphorus criterion. Even at reference sites, 27% of 26 samples exceeded the total nitrogen criterion (0.5 mg/L) and 65% exceeded the total phosphorus criterion (30 µg/L).

Preliminary results from the reference site study indicate that orthophosphate (one form of phosphorus) concentrations vary spatially between reference sites and vary seasonally (April–August) within a site (**FIGURE 4**). This is important when considering nutrient guidelines since nutrient concentrations at reference sites vary with geology, aerial deposition, vegetation, and other factors. Morphology, light availability, flooding frequency, and biological community structure can also influence how a particular waterbody reacts to specific nutrient concentrations.

The State Water Board is taking a different approach to developing nutrient objectives by using a risk-based framework, known as the Nutrient Numeric Endpoint (NNE) approach. The NNE approach selects nutrient response indicators, such as algal biomass or dissolved oxygen, that can be used to evaluate the risk of beneficial use impairment, rather than pre-defined nutrient limits that may or may not actually result in excessive algal growth (Tetra Tech 2006). In the SWAMP reference site study, although 73% of samples exceeded at least one of USEPA's nutrient criteria, chlorophyll a, an index of algal abundance and the primary response indicator used in the NNE, never exceeded the suggested level. Since the NNE uses a modeling approach, linking nutrient concentrations to response indicators, it inherently accounts for variability and bases impairment decisions on the actual response to nutrients that impair aquatic beneficial use.

In the future, the regional SWAMP will continue monitoring reference sites in order to provide perspective on guideline development and on urban creek monitoring. The regional SWAMP will also partner with stormwater monitoring programs in a regional watershed monitoring coalition.

Regional Monitoring of Contaminants in Fish and Shellfish

San Francisco Bay Area regional SWAMP monitoring started with studies conducted from 1998 to 2001 to monitor fish contamination in ten reservoirs, Tomales Bay, and along the San Mateo coast. The reservoirs were chosen for monitoring based on popularity for fishing and included Bon Tempe, Nicasio, and Soulajule reservoirs in Marin County; San Pablo and Lafayette Reservoirs in Contra Costa County; Lake Chabot, Shadow Cliffs, and Del Valle reservoirs in Alameda County; and Stevens Creek and Anderson reservoirs in Santa Clara County. Based on results from this monitoring, the Office of Environmental Health Hazard Assessment (OEHHA) developed fish consumption advisories for all of these reservoirs except for Shadow Cliffs, which did not have enough data for an advisory. SWAMP worked in collaboration with OEHHA, the California Department of Public Health, East Bay Municipal Utility District, East Bay Parks District, and county health departments to make this information public by developing fact sheets and posting signs in five languages. Data from this sampling provided the first indication that methylmercury is elevated to some degree in all Bay Area reservoirs, not just those that were influenced by mining, and that PCBs are high in fish from Lake Chabot. SWAMP studies are continuing in these and other reservoirs to develop and refine advisories.

Studies in Tomales Bay also led to a fish consumption advisory based on methylmercury concentrations in fish. Commercially grown oysters and clams in Tomales Bay, however, were shown to have low levels of methylmercury.

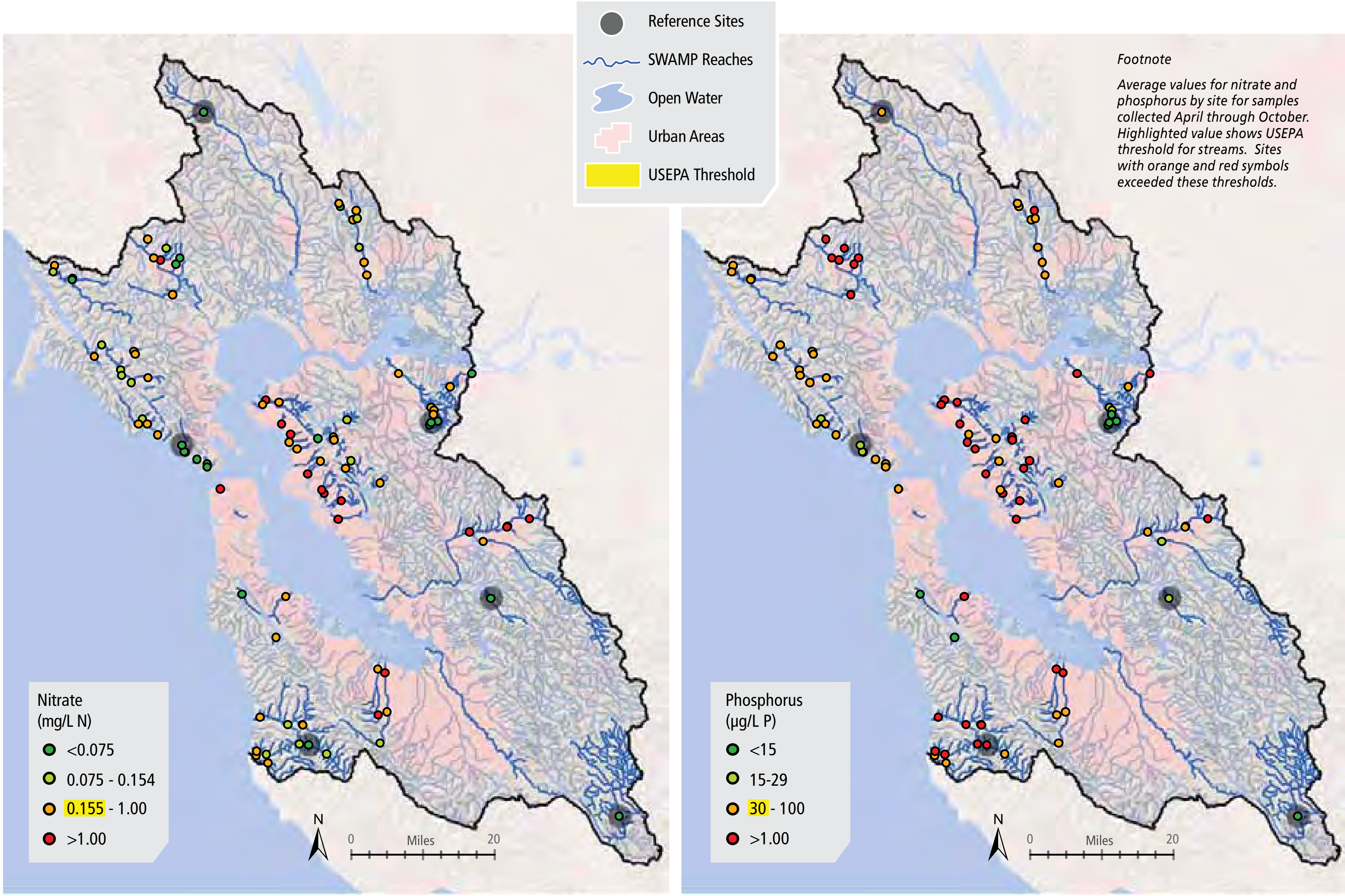
Advisories for the reservoirs and Tomales Bay can be found at OEHHA's web site: http://www.oehha.ca.gov/fish/so_cal/index.html.

Use of Regional SWAMP Data in Decision-Making

Section 303(d) of the 1972 Federal Clean Water Act requires that states develop a list (known as the 303(d) List) of water bodies that do not meet water quality standards (**page 42**). Section 305(b) of the Act requires a biennial summary of the quality of waters in each state. Regional SWAMP stream monitoring and fish contamination studies have resulted in 50 existing or proposed 303(d) listings for impaired lakes and streams in the Bay Area. In 2010, a report integrating 303(d) listings and 305(b) reporting requirements was issued. In this report, water bodies were classified into five categories:

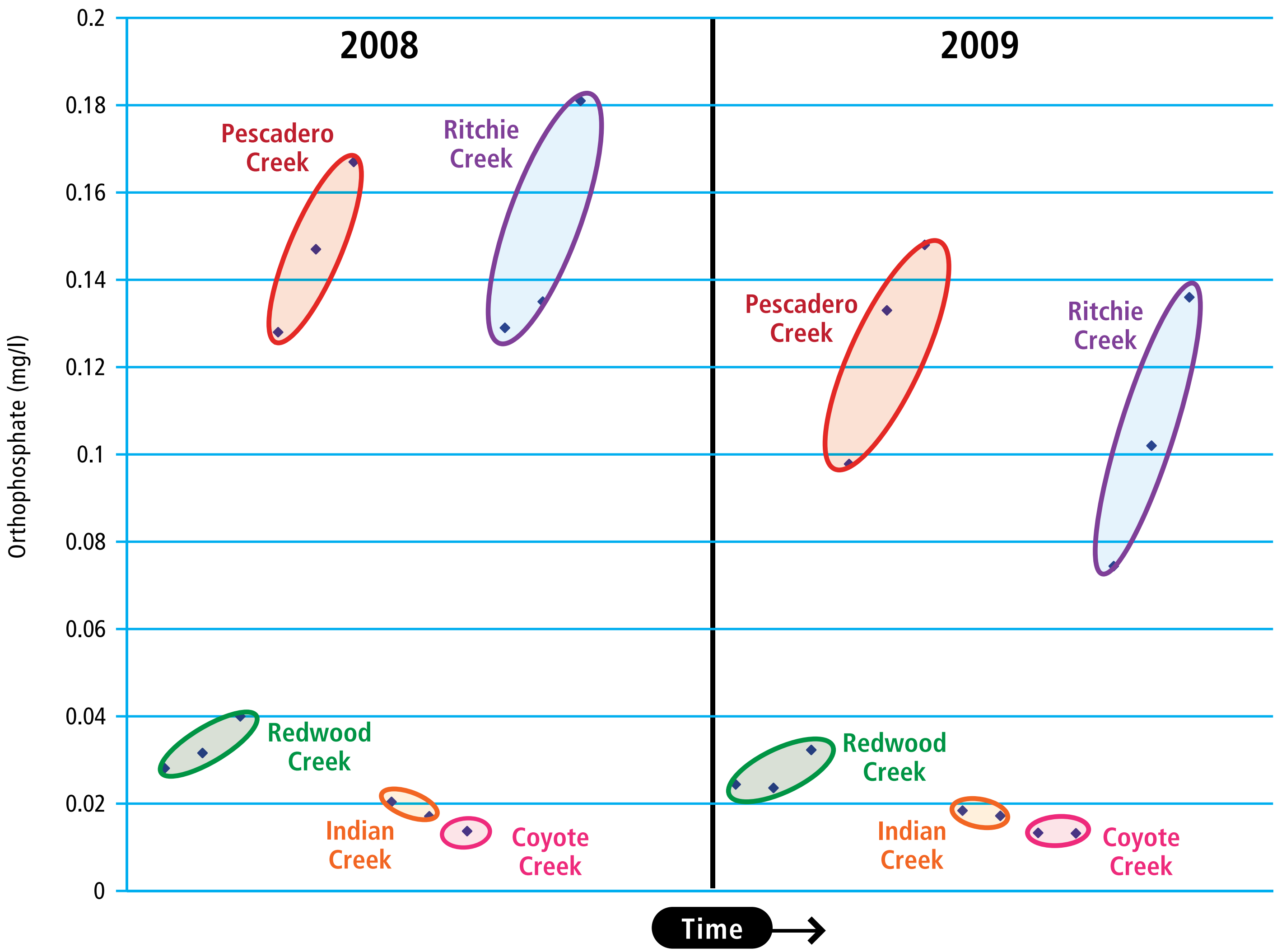
1) all beneficial uses protected,

2) some beneficial uses protected,



↑ **FIGURE 3**

Nitrate and phosphorus are constituents in fertilizers and animal wastes that can stimulate excessive growth of algae in streams and other aquatic ecosystems. Most of the locations visited during the April-October sampling period exceeded USEPA nitrate and phosphorus criteria. Of 249 samples, 70% exceeded the 0.155 mg/L nitrate criterion, and 93% exceeded the 30 ug/L total phosphorus criterion. Overall, nitrate and phosphorus concentrations were highest and most variable in streams draining urban areas, although some watersheds located upstream from urban influences, even some reference sites, had high nutrient levels.



← **FIGURE 4**
Preliminary results from a reference site study indicated that orthophosphate (one form of phosphorus) concentrations varied spatially among reference sites and seasonally at each site. These findings are important for considering appropriate nutrient guidelines.

3) not enough information,

4) impaired but no TMDL because remedies are in place, and

5) impaired and needs TMDL.

The State Water Board has also developed an interactive map to provide information on water quality in the state's waterbodies. Both the report and map are available at: http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml

Monitoring in the State SWAMP

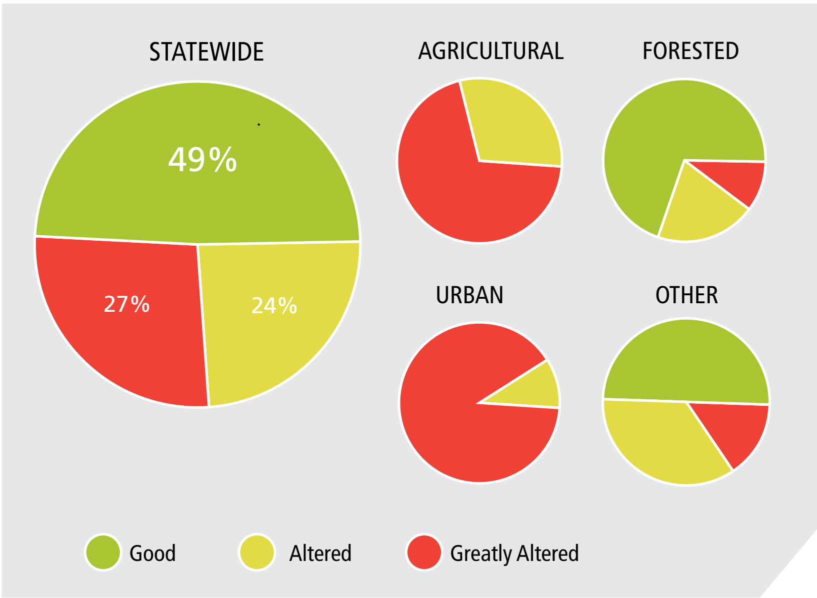
Statewide monitoring efforts include the Healthy Streams Initiative and monitoring of contaminants in fish. Committees for both of these monitoring efforts serve as workgroups for the California Water Quality Monitoring Council, a group established in 2007 to integrate and coordinate water quality and related ecosystem monitoring, assessment, and reporting performed by California Environmental Protection Agency (Cal/EPA) and the California Resources Agency (described further below) (http://www.swrcb.ca.gov/water_issues/programs/monitoring_council/). SWAMP's statewide surveys have yielded a great deal of valuable information on the condition of Bay Area water bodies.

California's Healthy Streams Initiative

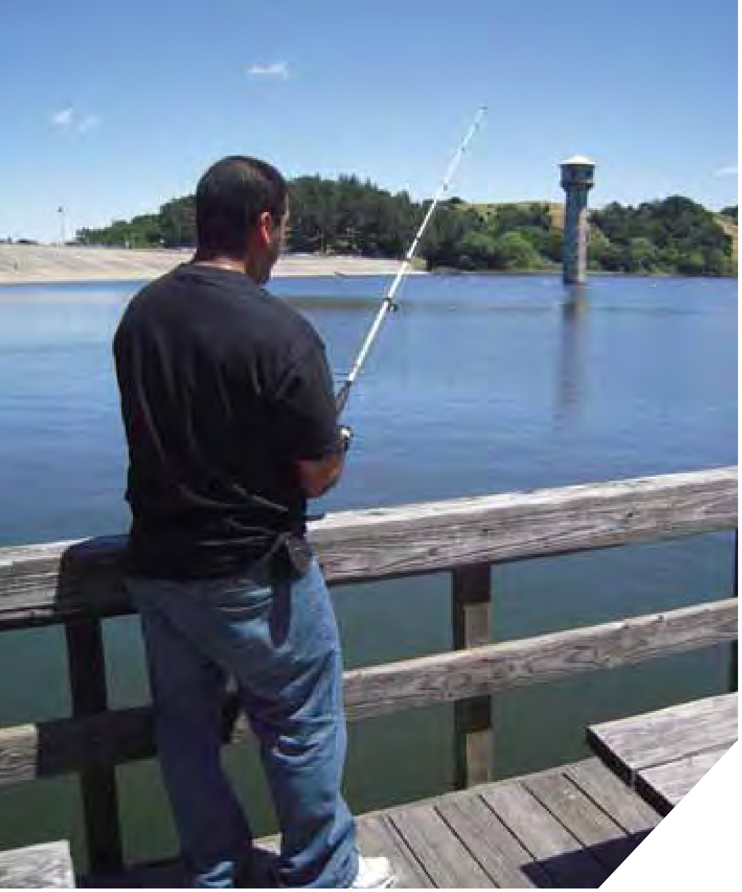
The Healthy Streams Initiative is designed to answer the question: Is aquatic life protected in wadeable streams? The Initiative consists of three integrated statewide studies. The first is a randomized survey to assess stream health. This study is a continuation of USEPA's Environmental Monitoring and Assessment Program (EMAP) monitoring in streams of the state. This type of study allows us to make statements about the percentage of creeks in the state that are classified as good, bad, or ugly. Measurements of physical habitat, basic water quality, and nutrients are made to help determine what stressors might be affecting creek organisms. Recent bioassessment results indicate that only 49% of the total perennial stream length in the state is in good biological condition; the remaining stream length is in either somewhat (27%) or greatly altered (24%) biological condition (Ode et al. 2010). Urban areas had the highest percentage of degraded habitat (90%), followed by agricultural areas (71%) (FIGURE 5).

In order to evaluate bioassessment data, expectations need to be established based on reference sites throughout the state. A statewide SWAMP reference site study, the second component of the Healthy Streams Initiative, was started in 2008. In this study, approximately 50 reference sites a year are monitored from a pool that will probably reach 500 sites. Information from this study will play a vital role in SWAMP's development of bio-objectives (described further below).

The third component of the Healthy Streams Initiative is the Stream Pollution Trends (SPoT) study. This statewide study is integrated with regional watershed monitoring programs in the Bay Area and Southern California. This study measures trends in sediment chemistry and toxicity at the bottom of 80 streams statewide. Ten of the streams are in the Bay Area. Seven of these sites will be sampled in coordination with MRP stormwater program monitoring to assist with coalition efforts in meeting the requirements of the MRP.



← FIGURE 5
Recent bioassessment results indicate that only 49% of the total stream length in California is in good biological condition. Biological condition in the remaining stream length were somewhat (27%) or greatly altered (24%). Urban areas had the highest percentage of highly altered habitat (90%), followed by agricultural areas (71%).



Fishing in Lafayette Reservoir. Photograph by Jay Davis.

In order to evaluate bioassessment data, and to protect the aquatic life beneficial use in streams of the state, SWAMP is developing bio-objectives for benthic macroinvertebrates. Technical Advisory, Stakeholder, and Regulatory committees have been formed to guide this effort. The vision of the State Water Board is to adopt narrative (rather than numeric) bio-objectives that are flexible enough to be implemented through quantitative regional Indices of Biological Integrity (IBI). The Bay Area Macroinvertebrate Bioassessment Information Network (BAMBInet), a coalition of agencies and volunteer groups that conduct bioassessments, is in the process of analyzing bioassessment data and evaluating whether a Bay Area specific IBI is needed.

A BOG in the SWAMP: Contaminants in California Fish

Answering the question "Are fish safe to eat?" is the focus of the other major statewide monitoring component of SWAMP. This monitoring is coordinated through the Bioaccumulation Oversight Group (BOG), a subcommittee of the SWAMP Roundtable and a workgroup for the California Water Quality Monitoring Council.

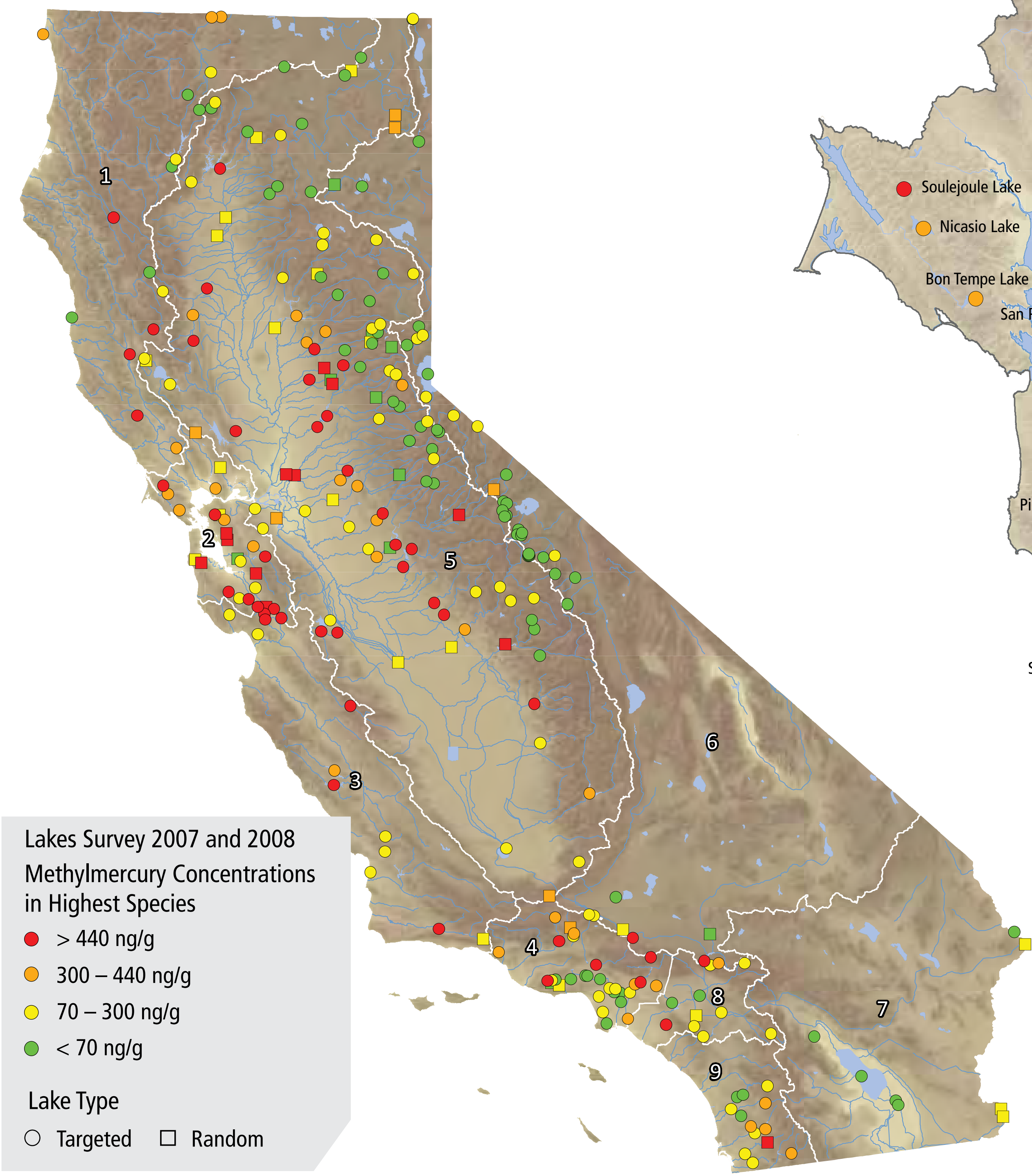
In 2007 and 2008 SWAMP monitored 272 lakes in California: 222 popular lakes and 50 randomly selected lakes. Twenty-six of these lakes were in the Bay Area. Results showed that methylmercury was the only pollutant measured that frequently reached concentrations high enough that OEHHA would consider recommending no consumption of the contaminated species (0.44 ppm). This degree of contamination was quite prevalent across the state. Overall, 56 of the 272 lakes surveyed (21%) had a species with an average concentration exceeding 0.44 ppm.

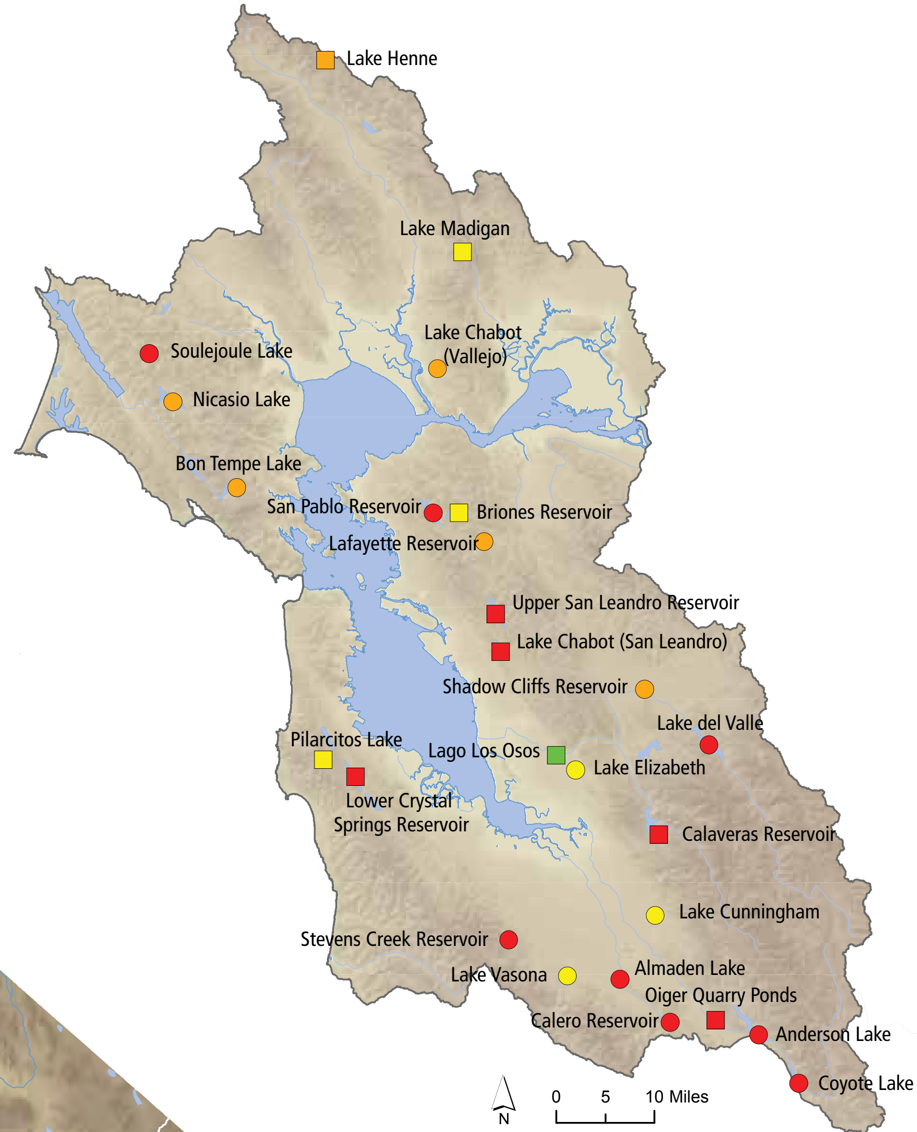
As in past studies (e.g., Davis et al. 2008, Melwani et al. 2009), clear differences were observed in methylmercury accumulation among species. As expected, relatively high concentrations were observed in species that are high trophic position predators, including largemouth, smallmouth, and spotted bass and Sacramento pikeminnow. Trout generally occupy a lower trophic position and accumulate lower concentrations of methylmercury and other pollutants, though a few exceptions to this pattern occur and were observed in this study. In general, higher concentrations of methylmercury were found in lower elevation lakes in Northern California, including the Bay Area, than in any other part of the state (**FIGURE 6**).

PCBs were second to methylmercury in reaching concentrations posing potential health risks to consumers of fish caught from California lakes. Far fewer lakes had PCB concentrations exceeding OEHHA's no consumption threshold (120 ppb), however, two of the lakes with the highest concentration of PCBs were Lake Vasona (also known as Vasona Reservoir) and Lake Chabot in the Bay Area. The regional SWAMP, in coordination with OEHHA, is following up on all of these results to collect data for the development of fish consumption advisories.

A report describing the study can be found at http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/lakes_study/lake_survey_yr2_full_rpt.pdf.

In 2009 and 2010, SWAMP is surveying contaminants in fish from bays, estuaries and coastal areas throughout California. In the Southern California Bight the survey was conducted in coordination with Bight '08, a monitoring program for the Southern California Bight administered by the Southern California Coastal Water Research Program. In the Bay Area the study was conducted primarily by the RMP in collaboration with SWAMP. Integration of these efforts, including development of standard protocols and SWAMP comparable quality assurance and reporting, increases the efficiency of gathering comparable statewide data and serves as a model for state and regional collaboration.





← ↑ **FIGURE 6**

In 2007 and 2008, SWAMP monitored fish from 272 lakes in California, 222 of which were selected because they are popular fishing locations and 50 which were randomly selected. Of these lakes, 26 were in the Bay Area. Of the pollutants measured, only mercury frequently reached concentrations high enough that OEHHA would consider recommending no consumption of the species (mercury > 0.44 ppm). Overall, 21% of the 272 lakes had at least one species with an average concentration exceeding 0.44 ppm.

The My Water Quality website (www.waterboards.ca.gov/mywaterquality) makes California water quality information available to the public

Efficient Use of Monitoring Resources Through SWAMP Comparability

Since SWAMP doesn't have the resources necessary to monitor all beneficial uses in all waterbodies, the Program has developed uniform and objective approaches to monitoring, quality assurance, and data management that allow for other programs to be "SWAMP comparable." SWAMP comparability allows for data from different programs to be combined and assessed using a common database: the California Environmental Data Exchange Network (CEDEN).

All State and Regional Water Board programs, as well as all programs that are funded or regulated by the Water Boards, will eventually be required to be SWAMP comparable. The RMP, for example, is a SWAMP comparable program. In addition, the Bay region's new Municipal Regional Stormwater Permit requires monitoring data from stormwater programs in Contra Costa, San Mateo, Santa Clara and Alameda counties, Vallejo, and Fairfield/Suisun to be SWAMP comparable. In order to assist projects and programs in becoming SWAMP comparable, SWAMP has written a Quality Assurance Program Plan (QAPrP), set up data management and quality assurance help desks, developed the SWAMP Advisor (user friendly software, similar to Turbo-tax, to develop a Quality Assurance Project Plan), created data and Quality Assurance Project Plan templates, and conducted trainings.

All SWAMP comparable data will be available through CEDEN. There are four regional data nodes that feed in to CEDEN: SCCWRP, Moss Landing Marine Labs, SFEI, and U.C. Davis. These data nodes populate CEDEN for their respective geographical regions and work together to develop rules for data management. Data from CEDEN can be viewed and downloaded at www.ceden.org.

The California Water Quality Monitoring Council

The California Water Quality Monitoring Council provides a new paradigm for collecting and providing information on water quality in California. The Council has focused on making water quality information available to the public by establishing a My Water Quality website (http://www.waterboards.ca.gov/mywaterquality/). The website has five portals that answer basic water quality questions.

- Is it safe to swim in our waters?
- Is it safe to eat fish and shellfish from our waters?
- Is our water safe to drink?
- Are aquatic ecosystems protected?
- What stressors and processes affect our water quality?

Each portal has one or more workgroups assigned to develop the portal, gather information, and display the information in the portal. SWAMP is currently in charge of the Safe-to-Eat portal, through the BOG, and the Aquatic Ecosystems in Streams portal through the Healthy Streams Initiative. Other workgroups have been set up to work on the portal for Aquatic Life in Wetlands, and the Safe-to-Swim and Safe-to-Drink portals.

Through SWAMP, CEDEN, and the California Water Quality Monitoring Council the state has made great progress in improving the efficiency and effectiveness of water quality monitoring and providing broader access to monitoring and assessment results. This information is being used by water quality managers to improve the effectiveness of regulatory programs, to provide comparable data of known quality to scientists, and to inform the public about the quality and use of our waters.

TRIBUTARY LOADS: AN UPDATE ON LARGE AND SMALL WATERSHEDS

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Highlights

- Recent studies have shown that small tributaries contribute significant loads of sediments and pollutants to the Bay, a change from thinking that most loading came from the Central Valley
- Monitoring in the Guadalupe River has confirmed that this watershed is contaminated with both mercury and PCBs and provides a substantial annual load to the Bay
- Monitoring in a small, highly urbanized watershed in Hayward, dominated by impervious surfaces, has shown that runoff volume and quality changes quickly in response to storms
- A watershed model being developed for the Guadalupe River will improve the accuracy of mass load estimates and provide a tool for forecasting changes in response to management actions
- Annual variation in watershed loads is a complex function of annual runoff, rainfall intensity, sources, and area of impervious surface in a watershed
- Reliable information on sediment and pollutant loads to the Bay is essential for implementation of TMDLs and other management actions

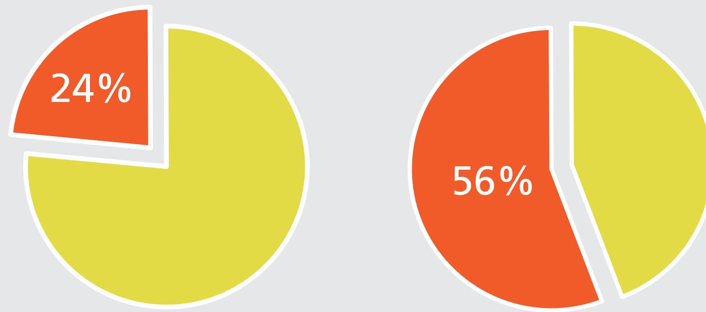
Stormwater runoff in the San Leandro Creek watershed. Photograph by Marcus Klatt.

Introduction

A decade ago, scientists and managers thought that the bulk of the sediments - and the associated pollutants - reaching San Francisco Bay came from runoff from the vast Central Valley watershed. It seemed to make sense. The Central Valley watershed drains an area that comprises about 40% of the area of the entire state of California and accounts for 90% of the water flow that reaches the Bay (Conomos 1979).

But did it really make sense? Much of the Central Valley watershed is flat, and it is characterized by a river delta, which spans thousands of square kilometers and where, under natural conditions, sediments are deposited before entering the Bay. Studies conducted under the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) suggest that the Central Valley is not the only major source of sediment and pollutant loads to the Bay. In fact, recently acquired information suggests that more than half the river inputs to the Bay originate from the smaller, local watersheds (**FIGURE 1**).

For example, ten years ago, a draft of the mercury Total Maximum Daily Load (TMDL) report summarized existing data, which suggested that 70% of the mercury entering the Bay came from the Central Valley, with only 20% coming via urban stormwater (Abu-Saba and Tang 2000). Now the estimate is that less than 40% of the mercury entering the Bay comes from the Central Valley, and slightly more than 40% comes from the urban tributaries. The current estimates of polychlorinated biphenyl (PCB) loads suggest that about 30% come from the Central Valley and 60% enter through urban stormwater runoff.



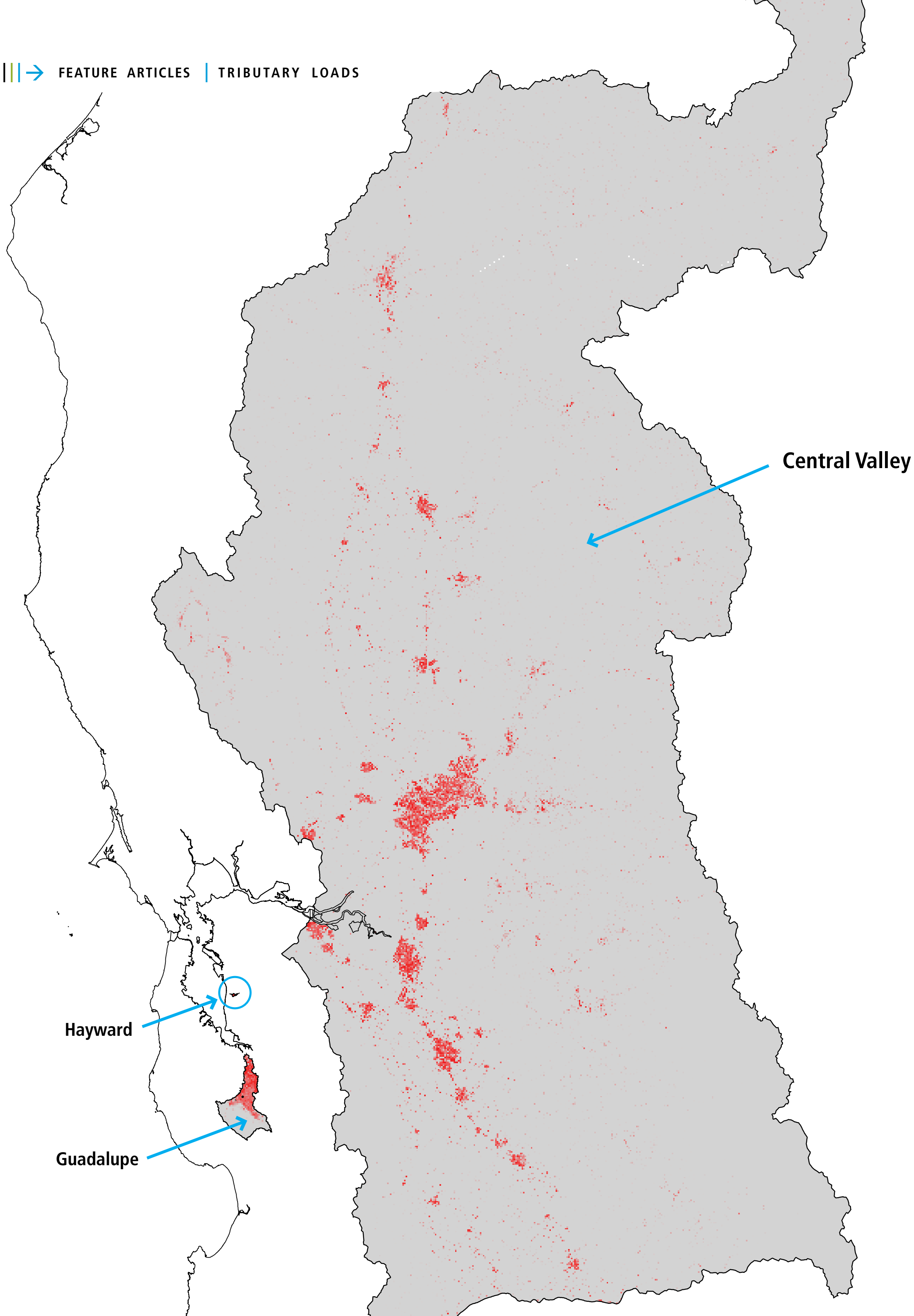
TEN YEARS AGO scientists thought that about 24% of the loads of sediments and pollutants carried by stormwater entered the Bay from small, local tributaries.

NEW ESTIMATES indicate that about 56% of stormwater loads come from small tributaries.

← **FIGURE 1**

This shift in thinking is mostly the result of studies in three watersheds, selected to cover a range in size, physical characteristics, and land uses. The sites include two small watersheds, one in Hayward and the Guadalupe River watershed in the South Bay. The Central Valley watershed is monitored at a sampling site located just downstream from the confluence of the Sacramento and San Joaquin rivers (**FIGURE 2**). A small number of samples have also been analyzed from the Coyote Creek watershed, adjacent to the Guadalupe River watershed, and from a number of other locations in the Guadalupe watershed, including a storm drain in an urban area located on San Pedro Road in San Jose.

Just two years ago, the 2008 *Pulse of the Estuary* presented an update on advances in understanding of pollutant mass loadings from rivers and local tributaries. Average loads at Mallard Island on the Sacramento River were reported to be about 1 million metric tons of suspended sediments, 211 kg of mercury, and 9.6 kg of polychlorinated biphenyls (PCBs). The 2008 Pulse of the Estuary also reported on the level of contamination found in the Guadalupe River and the substantial annual average loads of mercury (130 kg) and PCBs (0.9 kg) entering the southern portion of the Bay, which is associated with a history of mining and industry. Since then, a lot of work has been completed by the RMP Sources Pathways and Loadings Workgroup (SPLWG), and it is already time for another update.



← FIGURE 2

RMP studies in three watersheds, selected to cover a range in size, physical characteristics, and land uses, have contributed to a shift in understanding of contaminant loads to the Bay. The studies have assessed two small watersheds, one in Hayward and the Guadalupe River watershed in the South Bay. The large Central Valley watershed is monitored at a sampling site located just downstream from the confluence of the Sacramento and San Joaquin rivers.

Footnote: Red areas indicate urban portions of each watershed.

Findings from a Small, Highly Urbanized Watershed in Hayward

One location that has generated a lot of new information since 2008 is the small Hayward watershed. Its 4.5-square kilometer area is just a speck in comparison to the Central Valley's 154,000 square kilometers. This watershed has no natural channels (FIGURE 3), and there has been no historic gauging of water flows. Labeled Zone 4 Line A by Alameda County Flood Control and Water Conservation District, it does not correspond to any historically named creek, and being close to he Bay margin, the location gets relatively little rainfall compared to some of the higher elevation locations in the Bay Area. Land use is roughly evenly divided among industrial, commercial, and residential uses. Only 2% of the watershed is open space (ABAG 1995).

Contaminants that accumulate on paved surfaces in urban watersheds are washed into creeks and storm drains during wet weather. Photograph by Nicole David.

Studies in the Hayward watershed began in November 2006, in the early weeks of water year 2007. (Water years run from October 1 through September 30 and are named for the year in which they end.) A final report on that first study year was completed in 2009 (McKee et al. 2009). Overall, water year 2007 was rather dry, and the 21 storms that did occur were not large. But the measurements made during those storms were sufficient to demonstrate a rapid response of both flow and pollutant concentrations to both the onset and end of rainfall events. These quick responses can be attributed to the small size of the watershed and the predominance of impervious surfaces, which do not allow water to slowly seep into the ground.

Concentrations of total mercury in water samples varied by a factor of about 30, and stormflow concentrations of PCBs reached levels about 100 times greater than dry-weather flow conditions. Overall variation in pollutant concentrations between base flow and storm flow ranged between factors of just four for arsenic to 2000 for suspended sediments. Variability in loads was even greater. The largest daily sediment loads in water year 2007 were about 100,000 times greater than the smallest loads.

As expected, because pollutants of concern tend to associate with particles, pollutant concentrations correlated with suspended sediment concentrations – the greater the concentrations of suspended sediments in the water sample, the higher the pollutant levels. Water years 2008 and 2009 continued to have relatively low flows, but the data gathered during those years were sufficient to confirm the strong relationships between flow and suspended sediment and pollutant concentrations (FIGURE 4). Understanding these relationships is a critical step to calculating total loads to the Bay.

Now with three years of data, there is information on climatic variability. For example, suspended sediment loads varied from over 100 metric tons in water year 2007 to only 57 metric tons in water year 2009. Loads of mercury and PCBs varied less and in the opposite direction ranging from 19–23g and 9–11g in water years 2007 and 2009. In terms of a comparison, the Hayward location appears to be more contaminated with methylmercury, cadmium, copper, lead, zinc, PCBs, polybrominated diphenyl ethers (PBDEs), DDT, and dieldrin, while the Guadalupe River, where monitoring has also occurred, is more contaminated with total mercury, chromium, and nickel, associated with the mining history and serpentine geology of this watershed. Further data were collected in both the Guadalupe River watershed and the Hayward watershed this year, water year 2010. These data may confirm, refine, or modify these comparisons. Overall, these studies have provided valuable contributions to answering the priority management questions articulated in the RMP Small Tributary Loading Strategy (page 30).

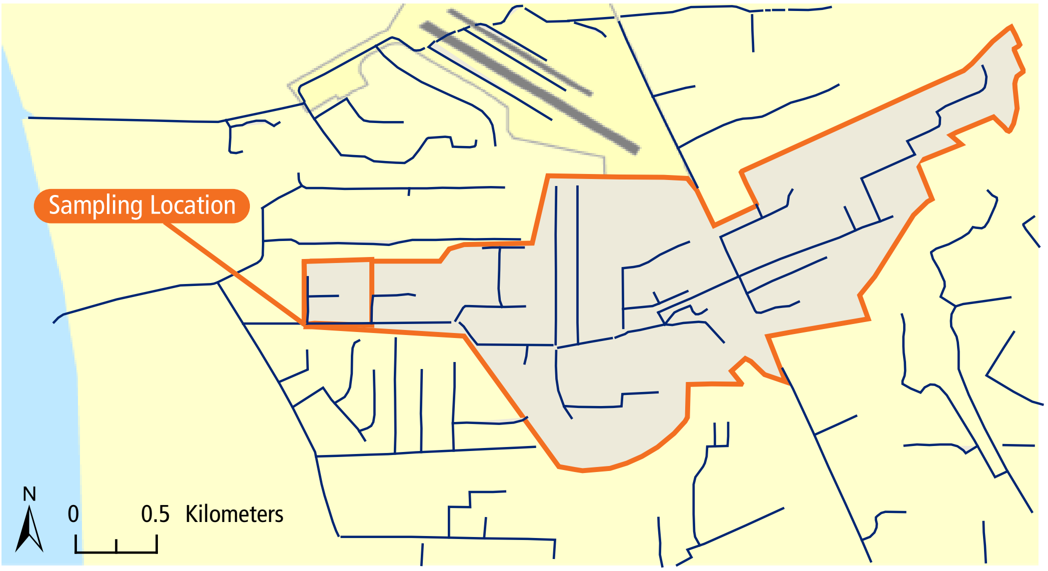
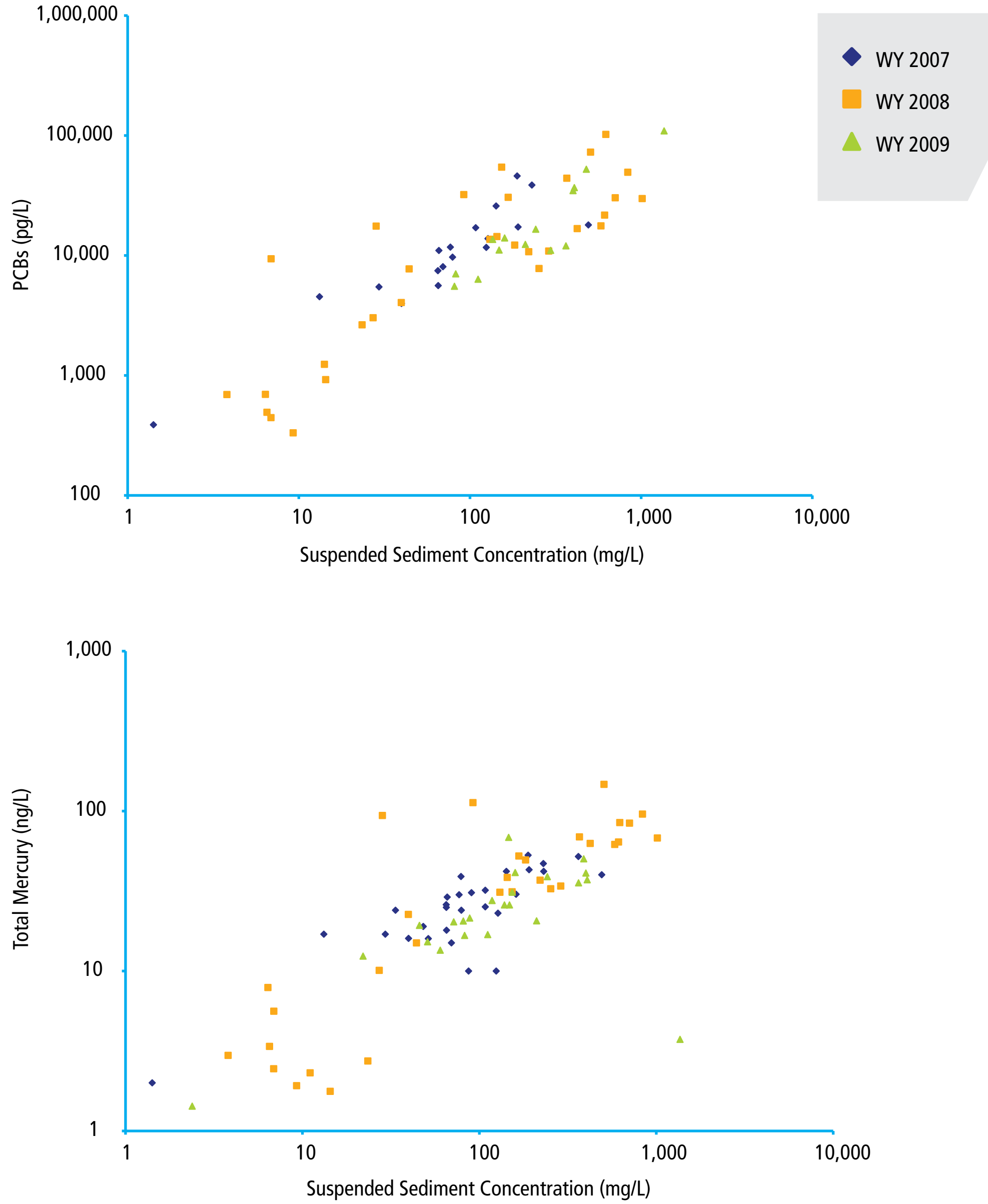


FIGURE 3

TOP:
Sampling location, watershed boundary, and storm-drain channel network in the small Hayward watershed. See FIGURE 2 for location.

BOTTOM:
Hayward watershed sampling location. Most of the drainage is storm drains and culverts. About one third of the drainage network is open to the air.

Photograph by Alicia Gilbreath.



← **FIGURE 4**

Concentrations of total mercury (top) and total PCBs (bottom) in comparison to suspended sediment concentrations in water years 2007, 2008, and 2009. Since mercury and PCBs associate with sediment particles, higher sediment concentrations lead to higher contaminant concentrations. The strong relationships between pollutant and suspended sediments concentrations are useful for estimating loads to the Bay.

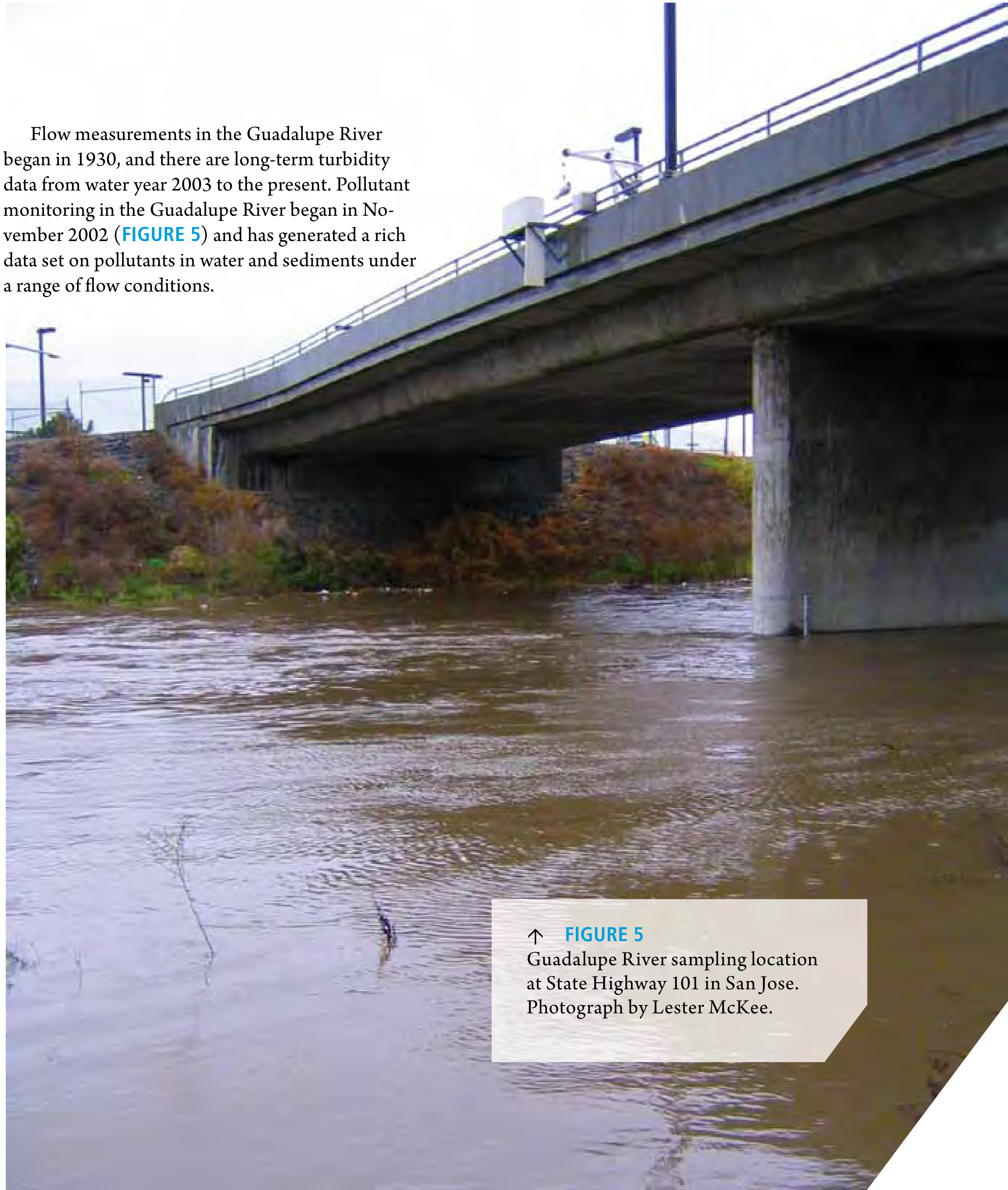
Modeling the Guadalupe River Watershed

In the Guadalupe River watershed, the focus is shifting from sampling and analysis to modeling. In general, environmental models build on results from monitoring programs to simulate aspects of the ecosystem that are too large or complex to understand without very costly sampling and analysis. The extensive dataset that the RMP has collected and the important management issues in the watershed make the Guadalupe River an ideal location to explore the use of predictive modeling to understand water flows, sediments, and pollutants in the small, urban tributaries that flow into San Francisco Bay.

The Guadalupe River is one of 13 watersheds draining into Lower South San Francisco Bay. It flows from its headwaters in the Santa Cruz Mountains, past the San Jose Airport, and into the South Bay at Alviso Slough. Though very small in comparison to the Central Valley, the Guadalupe River watershed is the fourth largest in the Bay Area, covering about 500 square kilometers.

The watershed was home to the historic New Almaden Quicksilver Mining District, which was once the largest producing mercury mining area in North America. It is also heavily contaminated with PCBs, a legacy of industrial activity during the 1950s through the 1970s. The San Francisco Bay mercury TMDL calls for a 98% reduction in the load entering the Bay from the Guadalupe River. The PCB TMDL also calls for enormous reductions, more than 90% from runoff across the urban landscape (San Francisco Bay Regional Water Quality Control Board 2006, 2008).

Flow measurements in the Guadalupe River began in 1930, and there are long-term turbidity data from water year 2003 to the present. Pollutant monitoring in the Guadalupe River began in November 2002 (FIGURE 5) and has generated a rich data set on pollutants in water and sediments under a range of flow conditions.



↑ FIGURE 5
Guadalupe River sampling location at State Highway 101 in San Jose. Photograph by Lester McKee.

Pollutant monitoring in the Guadalupe River has generated a rich dataset to support modeling

The first goal of the Guadalupe Watershed Model Project was to develop a hydrologic model. Hydrologic models use rainfall, land use, and other parameters to simulate water flow through the watershed. Important aspects of model development include calibration, in which a set of monitoring data are used to refine the model simulations, and validation, in which a separate set of monitoring results are compared to modeled results as a test of the model's ability to accurately simulate field conditions. The next goals were to extend the model to include sediments, mercury, and PCBs and to improve the accuracy of mass load estimates (**FIGURE 6**).

A report on the hydrologic component of the model was completed in 2009 (Lent et al. 2009). The model was developed using public domain software known as Hydrological Simulation Program-Fortran (HSPF). HSPF is a part of the Better Assessment Science Integrating Point and Non-point Sources (BASINS) modeling system, and it is jointly maintained by the U.S. Environmental Protection Agency (USEPA) and the U.S. Geological Survey (USGS). Prior to its adoption for the Guadalupe Watershed Model Project, HSPF had been used to model mercury loads, but it had never been used for PCBs.

Setting up the model required precise delineation of the watershed. Upstream reservoirs and their watersheds were excluded, so that their inputs could be accounted for as point sources, eliminating the need to model complex internal reservoir dynamics. Model setup partitioned the area into divisions or subbasins, which were based on topography, drainage patterns, meteorological variability, soil types, land cover, and land use, keeping in mind the future uses and management questions that the model is designed to answer (**FIGURE 7**).

Calibration of the model involved an iterative process of making changes to model parameters, running the model, and comparing the simulated results to field measurements. Data from water years 2000–2005 were used to calibrate the model, while data from water years 2006–2007 were used for validation. When tested with the validation data, the model performed well for daily average flow and storm events. The model could generally simulate peak flows during storm events, with simulated peaks occurring within several hours of the peaks that had been observed in the field. The model was less successful, however, at simulating low-flow events.

One shortcoming with the initial model calibration was that water years 2000–2005 were all relatively dry. Incorporating available stream flow and precipitation data from a wetter period, water years 1995–1999, has now been completed. Water year 1995 had the highest peak flow on record, and water year 1998 was also exceptionally wet. Other suggested improvements being considered in the latest version of the model include adding urban irrigation, refining estimates of how much of the surface is impervious, considering meteorological conditions on a finer scale, and continuing to evaluate calibration factors that were taken from national rather than local studies.

Preliminary results for calibration and validation of the sediment component of the model are complete. Calibration of the sediment component involves adjusting the rates of sediment accumulation and removal from varied land-use types and adjusting other parameters that control erosion and deposition. Validation compares simulated suspended sediment concentrations to those observed in the field. The next step will be to add the mercury and PCB components. The dataset for mercury in the watershed is extremely rich, with over 600 data points on concentrations in stream sediments and water collected through other San Francisco Estuary Institute projects and by agencies, universities, and consulting firms over the last 25 years. PCB data are rarer but the PCB component of the model will benefit to some extent from the way it contrasts in source and runoff relationships to mercury. Ultimately, the model will be used to confirm estimates of mercury and PCB loads and to determine when and from where the pollutants are transported. It will also be used to investigate the effects of land-based management practices and land-use changes on pollutant loads.

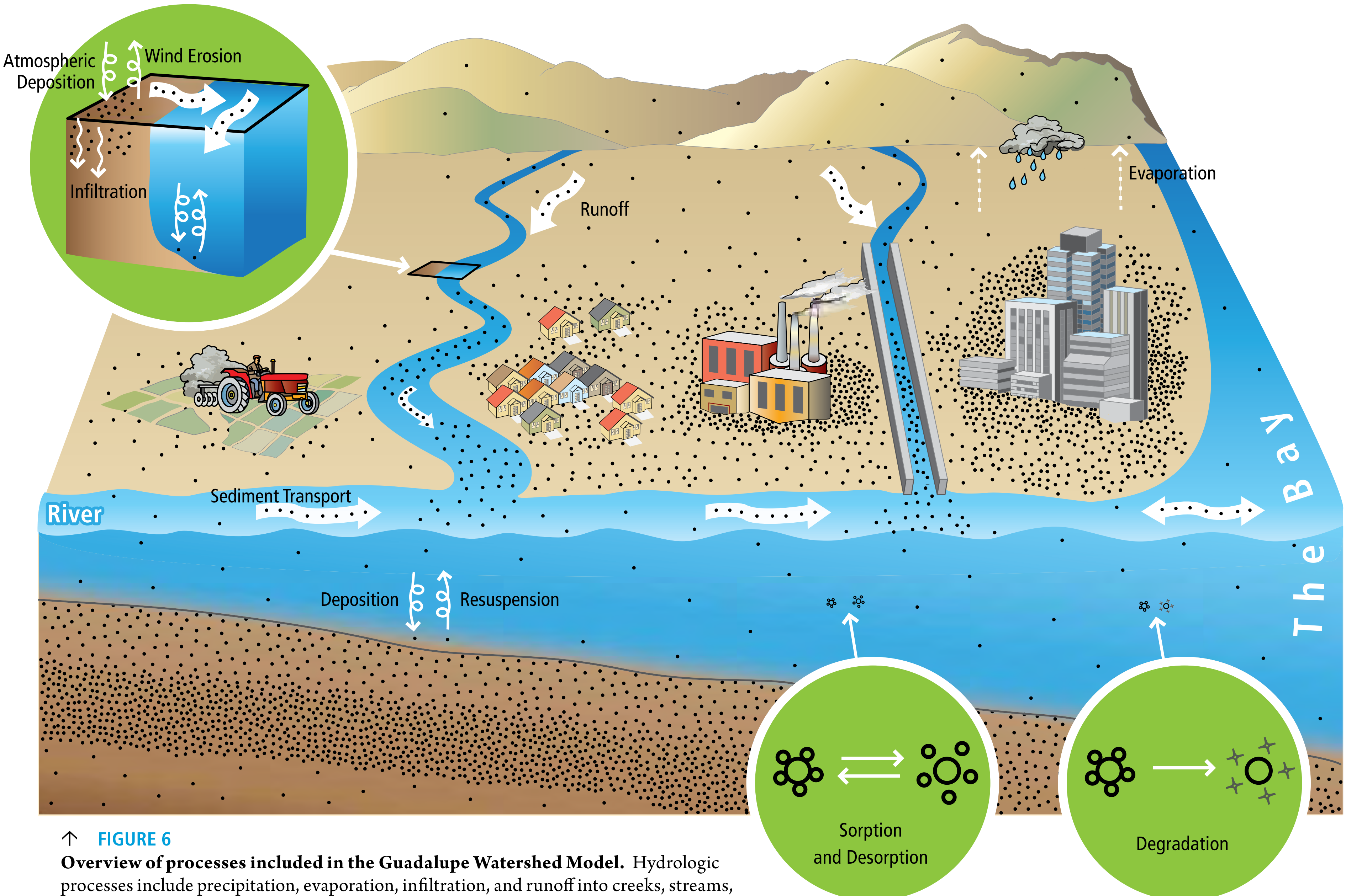


FIGURE 6

Overview of processes included in the Guadalupe Watershed Model. Hydrologic processes include precipitation, evaporation, infiltration, and runoff into creeks, streams, and storm drains. Particle transport processes on land include atmospheric deposition and accumulation in soil, and wind erosion and runoff from soil. Particle transport in creeks, streams, and storm drains include advection (transport with moving water), deposition to bed sediments, and erosion from bed sediments. Additional contaminant cycling processes that occur both on land and in water include partitioning (sorption and desorption from sediment particles) and degradation.

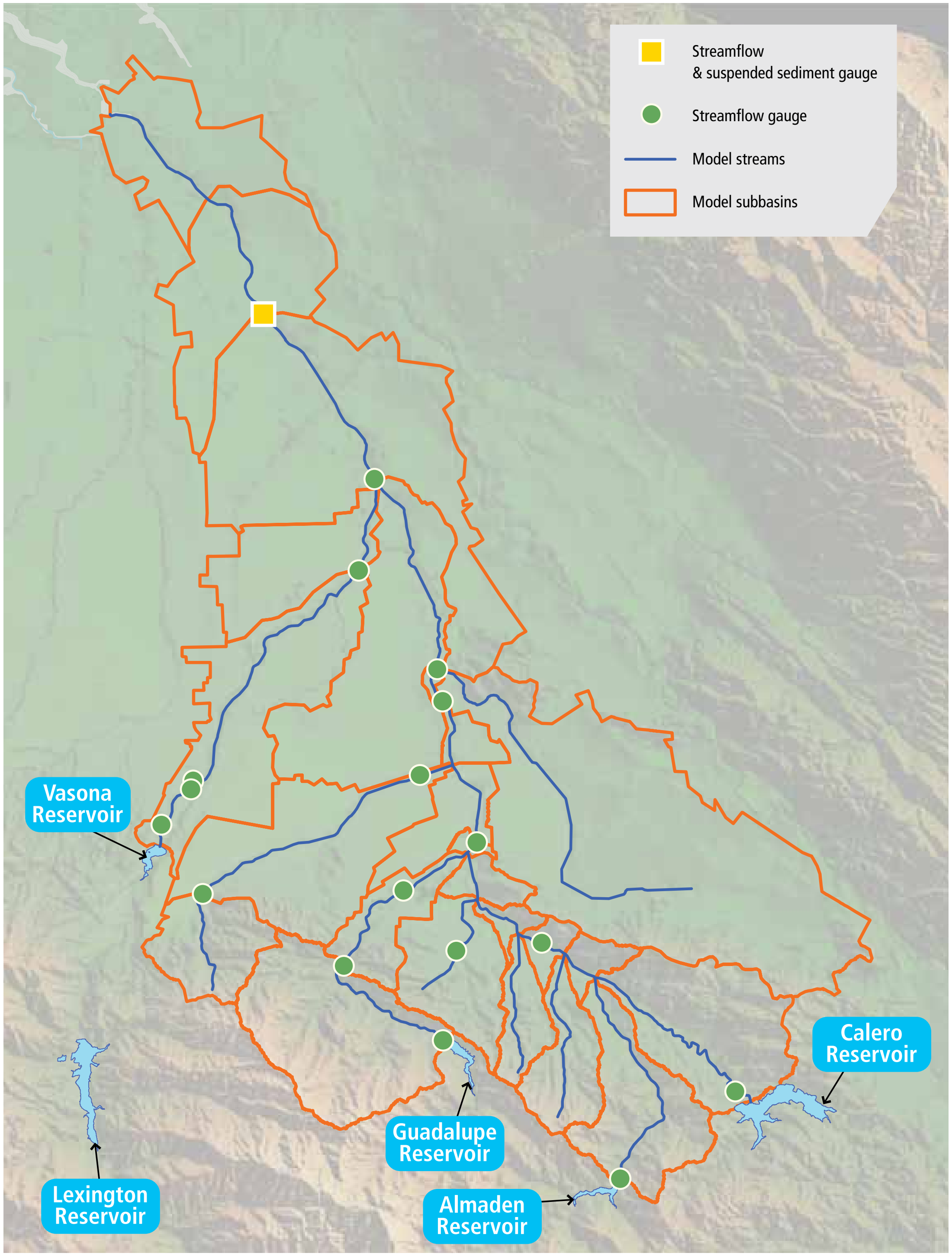


FIGURE 7

The Guadalupe River watershed, including streamflow and suspended sediment gauges. See Figure 2 for location. The Guadalupe Watershed Model divides the watershed into subbasins, which are based on topography, drainage patterns, meteorology, and soil type.

Loads from California's Largest Watershed

Continued monitoring of the inputs of sediments and pollutants from the Central Valley is providing data to improve the estimates of loads and to document variation over time. The RMP began loading studies at Mallard Island in December 2001. The USGS has conducted sediment studies at the site since 1994, and outflow data were available from 1956 onward. The relationships between suspended sediment and pollutant concentrations, coupled with continuous turbidity information, were used to extrapolate continuous records of suspended sediment and pesticide loads.

The findings indicate that loadings from the Central Valley are less than had been previously estimated. Recent estimates suggest that total mercury loads from the Central Valley watershed are less than half of what had been estimated a decade ago (David et al. 2009). The change reflects both better measurement techniques and a real change in loading.

Part of the story of why estimates have decreased is based on improvements to methods used to measure sediment loads and pollutant concentrations. Recent work has focused on collecting samples during large storms and improvements in the methods used to calculate pollutant loads. Traditionally, monitoring programs have correlated pollutant concentrations with river flow to determine loads. The RMP's use of continuous suspended sediment concentrations instead of river flow to calculate loads at Mallard Island takes advantage of the strong relationship between pollutant concentrations and suspended sediments.

Sample collection at Mallard Island. The Mallard Island sampling site is located just below the confluence of the Sacramento and San Joaquin rivers (see FIGURE 2). Since 2002, the RMP has monitored the site to estimate concentrations and loads of pollutants that enter the Bay from the Central Valley watershed. Photograph by Marcus Klatt.

Another factor in decreased load estimates from the Central Valley is a change in the sediment regime. The 2009 Pulse of the Estuary reported an abrupt decrease in suspended sediment inputs to the Bay, which occurred in a single step in 1999 (Schoellhamer 2009). The most likely explanation for the 40% decrease in suspended sediment concentrations in Bay waters is the depletion in the erodible pool of sediments that had entered the Bay through the Sacramento-San Joaquin River Delta since the Gold Rush. Decreases in suspended sediment concentrations have not been as apparent at Mallard Island as they have been at monitoring locations within the Bay. However, the decrease may signal an increasingly lower contribution of the Central Valley to the total sediment and pollutant loads to the Bay (McKee et al. 2006).

What's the Effect of the Weather?

In general, it seems intuitive that loads of sediments and pollutants to San Francisco Bay would be tightly linked with rainfall. In a wet year, loads should be high, and in a dry year, loads should be lower. In fact, the story is more complicated. The timing, strength, and duration of storms, geology, soil types, and land uses all affect loading.

For example, each year the Pulse of the Estuary reports on latest monitoring results, including rainfall, riverine flow, and pollutant loads. Mercury loads from the Guadalupe River were relatively high in 2003, while estimated loads from the Delta were high in 1995, 1997, 1998, and 2006 (**FIGURE 8**).

But in terms of regional rainfall, 1995, 1998, 2005, and 2006 were all wet years. Water flow from the Guadalupe River was relatively high in 2006, about twice the flow in 2003, but mercury loads were relatively low.

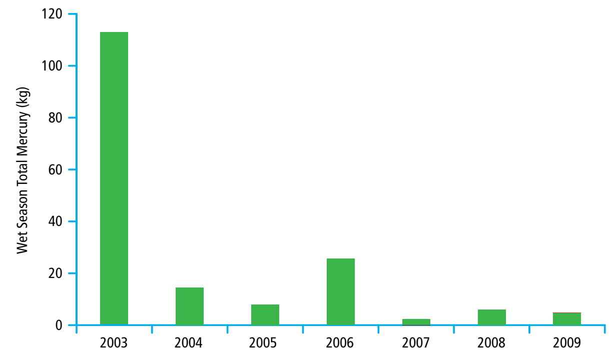
Why were 2006 mercury loads from the Guadalupe River lower than might be predicted from the annual flow? The most likely explanation is that the storms that season were all small, not large enough to mobilize the sediments from contaminated mining sites that would have transported mercury to the Bay. In general, loads can be presumed to follow climatic factors, but it is important to remember that there are complexities to the story and these are not always understood unless climatic years closer to the extremes are monitored. Watersheds, like the Guadalupe River watershed, that are contaminated with mining or industrial legacies show much greater variability in water quality and annual loads in relation to climatic variation than do watersheds with highly impervious surfaces and more moderate contaminant sources, such as those associated with residential land use.

Recent years have been dry, and it will be exciting to see results from some of the big storms that have occurred during water year 2010. In October 2009, San Francisco was hit by the biggest storm event since the 1960s. The City of San Francisco set a record for the most rain within a 24-hour period since record-keeping began in 1849. During the same event, the monitoring station in Hayward received a rare long-duration storm of medium to low intensity, estimated to have been about a 30-year storm in both rainfall and runoff. In contrast, the Guadalupe River had high rainfall in the mountains but very light rainfall in the City of San Jose. RMP sampling teams stationed in Hayward and at the Guadalupe River worked through the storm, successfully monitoring the time leading up to the event; the rise, peak and fall of flow; and the aftermath of the storm (**FIGURE 9**). When available, the results may transform the current views of stormwater flow and pollutant loading to the Bay.

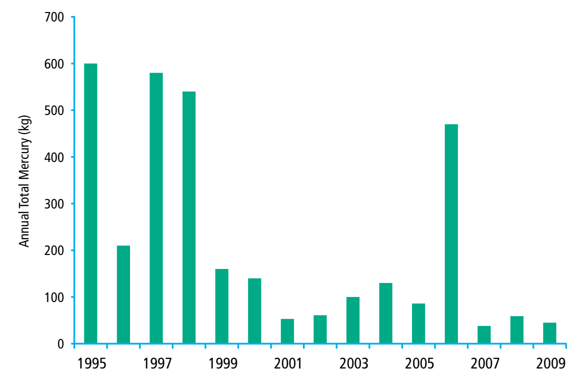
Summary of Loads and the Regional Assessment

The RMP has made a considerable effort to accurately quantify loads for three tributaries. Normalizing loads to area provides a means of comparing the degree of contamination of different watersheds (**TABLE 1**). By unit area, the Sacramento River yields lower loads of suspended sediments, mercury, and PCBs than the small tributaries. This result might be expected, given the large size of the Central Valley watershed and the multitude of places for sediment and contaminants to be trapped in soils, floodplains, river

Mercury from the Guadalupe River



Mercury from the Delta



↑ **FIGURE 8**
Mercury loads from the Guadalupe River were relatively high in 2003, while estimated loads from the Delta were high in 1995, 1997, 1998, and 2006. However, 1995, 1998, 2005, and 2006 were all wet years. Water flow from the Guadalupe River was relatively high in 2006, about twice the flow in 2003, but mercury loads were relatively low. Why were 2006 mercury loads from the Guadalupe River lower than might be predicted from the annual flow? The most likely explanation is that the storms that season were all small, not large enough to mobilize the sediments from contaminated mining sites that would have transported mercury to the Bay.

sediments, and vegetation. In contrast, the Guadalupe River yields very high loads of mercury in relation to its watershed area, due to its mining history. The Hayward watershed appears to yield slightly higher loads per unit area of PCBs and copper, but since the data are quite variable, it might be better to say these loads are similar to the Guadalupe River.

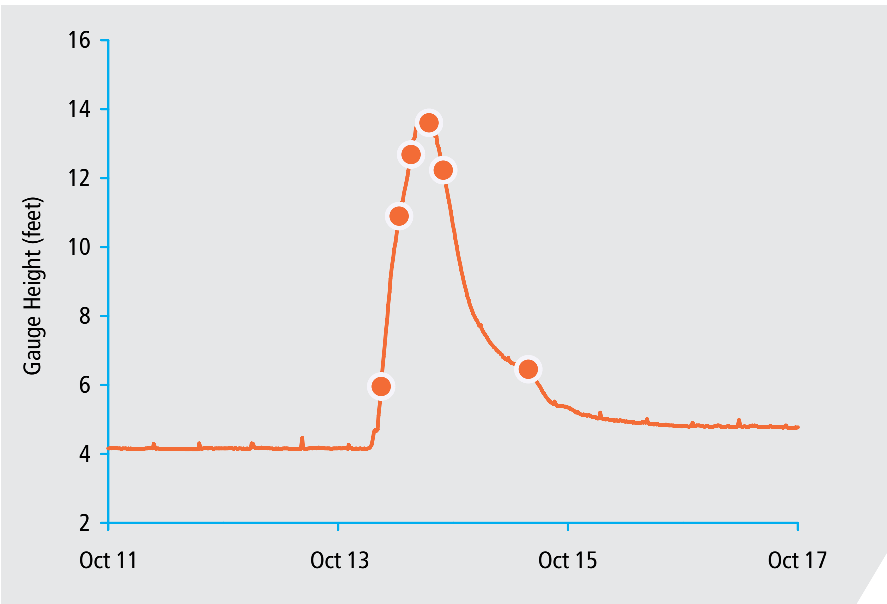
Recent studies have also provided improved estimates of regional suspended sediment loads. The current best estimate of total suspended sediment loads entering the Bay from the Central Valley is 1 million metric tons per year, and the estimate of inputs from the local watersheds is 1.3 million metric tons per year (TABLE 2; Lewicki and McKee 2009). The new estimates of the relative contribution of the small tributaries to the total sediment load entering the Bay will have a big effect on management actions, including TMDLs and ongoing plans for wetland restoration.

Next Steps in Tributary-Load Monitoring

Important questions still remain about the loads of sediments and pollutants in stormwater runoff:

- Which tributaries contribute (or potentially contribute) the most to impairment of San Francisco Bay?
- What are the concentrations and loads of pollutants of concern flowing from the tributaries to the Bay?
- How are those concentrations and loads changing over time?
- What will be the effects of management actions on concentrations and loads?
- Where can management actions have the greatest effect?

The RMP's Small Tributary Loading Strategy (page 30) and the multi-year watershed loading sampling plan that will guide monitoring performed for the RMP and the Municipal Regional Permit (page 8) call for prioritizing watersheds for study, optimizing sampling designs, and determining information needs for estimating loads by specific land uses. Several RMP projects in 2010 are supporting these goals. Greenfield et al. (2010) developed a watershed classification scheme. Melwani et al. (2010) completed a study based on three years of loading data from the Hayward and Guadalupe River watersheds, in which statistical and cost analysis showed options for more effective monitoring designs. Monitoring data and modeling based on work in the Hayward watershed, the Guadalupe River, and at Mallard Island will continue to provide a foundation for these efforts.



Footnote: Gauge height on the Guadalupe River during the October storm. Dots indicate timing of sample collection.

← FIGURE 9

In October 2009, San Francisco was hit by the biggest storm event since the 1960s. The City of San Francisco set a record for the most rain within a 24-hour period since recordkeeping began in 1849. During the same event, the monitoring station in Hayward received a rare long-duration storm of medium to low intensity, estimated to have been about a 30-year storm in both rainfall and runoff. In contrast, the Guadalupe River had high rainfall in the mountains but very light rainfall in the City of San Jose. RMP sampling teams stationed in Hayward and at the Guadalupe River worked through the storm, successfully monitoring the time leading up to the event; the rise, peak and fall of flow; and the aftermath of the storm. The results from this sampling may transform current views of stormwater flow and pollutant loading to the Bay.

Parameter of Interest	Central Valley	Guadalupe River	Hayward
Watershed Area (square km)	154,000	414	4.47
Total Loads			
Flow (million cubic meters)	24,278	58	0.784
Suspended Sediment (metric tons)	1,000,000	14,000	146
Total Mercury (kg)	211	130	0.029
PCBs (kg)	9.6	0.9	0.013
Total Copper (kg)	No data	890	13.5
Loads Per Unit Area			
Flow (million cubic meters per square km)	0.158	0.140	0.175
Suspended Sediment (metric tons per square km)	6.5	34	33
Total Mercury (g per square km)	1.4	314	6.5
PCBs (g per square km)	0.062	2.2	3.0
Total Copper (g per square km)	No data	2150	3017

↑ TABLE 1

The RMP has made a considerable effort to quantify loads for three tributaries. Total loads of sediment, PCBs, and mercury are greatest from the larger watersheds. Normalizing loads to area provides a means of comparing the degree of contamination of different watersheds. Per unit area, the Sacramento River yields lower loads of suspended sediments, mercury, and PCBs than the small tributaries. In contrast, the Guadalupe River yields very high loads of mercury in relation to its watershed area, due to its mining history. The Hayward watershed yields similar loads per unit area of PCBs and copper to the Guadalupe watershed.

Region	Sediment Load (metric tons per year)
Central Valley via Sacramento River	1,000,000
Small Tributaries to RMP Bay Segments	
Rivers	27,353
Suisun Bay	203,453
Carquinez Strait	25,693
San Pablo Bay	281,789
Central Bay	246,170
South Bay	270,202
Lower South Bay	214,940
Total Small Tributary Load	1,269,606

↑ TABLE 2

New estimates of the relative contribution of the small tributaries to the total sediment load entering the Bay have important implications for management initiatives, including TMDLs and wetland restoration. The current best estimate of total suspended sediment loads entering the Bay from the Central Valley is 1 million metric tons per year, and the estimate of inputs from the local watersheds is 1.3 million metric tons per year.

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