# The Pulse of the Estuary

2007

## Monitoring and Managing Water Quality in the San Francisco Estuary

35 Years After the Clean Water Act

A report published by the San Francisco Estuary Institute
and the Regional Monitoring Program for Water Quality in the San Francisco Estuary

This report should be cited as:

San Francisco Estuary Institute (SFEI). 2007. The Pulse of the Estuary: Monitoring and Managing Water Quality in the San Francisco Estuary. SFEI Contribution 532. San Francisco Estuary Institute, Oakland, CA.

Cover Photograph:

East Bay Municipal Utility District wastewater treatment plant. Photograph by Greg Keller.

Contribution No. 532

# The Pulse of the Estuary

2007

## Monitoring and Managing Water Quality in the San Francisco Estuary

35 Years After the Clean Water Act

A report published by the San Francisco Estuary Institute
and the Regional Monitoring Program for Water Quality in the San Francisco Estuary

# Summary of this Edition

Technical terms defined in Glossary on Inside Back Cover

**The Pulse of the Estuary** is the Annual Report of the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). This edition of the Pulse provides a historical perspective on progress in improving Bay water quality since President Nixon signed the Clean Water Act (CWA) into law in 1972. Thirty five years later it is clear that tremendous progress has been made, but significant and challenging water quality problems still remain (**page 5**). Through an increased emphasis on implementation of CWA provisions, we are now at another historic turning point and are poised to make one more significant step forward in improving Bay water quality (**page 23**).

In 1972 the Bay suffered from severely degraded water quality. The discharge of poorly treated wastewater, primarily from publicly-owned treatment works (POTWs) serving the Bay Area's growing population, was the cause of large and frequent fish kills, unsafe levels of bacteria in water and shellfish, and a notoriously foul stench (**page 7**). The CWA provided a major impetus toward cleaning up the Bay by setting clear goals and supplying over a billion dollars that supported construction of POTWs. In response, POTWs (**page 7**) and industrial wastewater dischargers (**page 18**) have achieved significant reductions in their emissions of pollutants into the Bay, and the most noticeable problems of the 1970s have been solved (**page 59**). Inputs of organic waste and nutrients have been greatly reduced and no longer cause fish kills or odor problems. Bacterial contamination has also been reduced. Inputs of toxic pollutants to the Bay also declined dramatically as a result of improved wastewater treatment (**page 7**) and enforcement of the CWA.

Another form of progress in management has been made possible by advances in scientific understanding of Bay water quality. Copper contamination in the Bay was a major concern in the 1990s. An evaluation of the issue by the Water Board and stakeholders, based on an extensive dataset provided by the RMP and studies showing that most of the copper in the Bay is bound up in a harmless form, concluded that the existing water quality objectives were inappropriately low (**page 79**). These findings led to new water quality objectives for copper in the Lower South Bay (less stringent but still considered fully protective of the aquatic environment), pollution prevention and monitoring activities to make sure concentrations remain below the objectives, and the removal of copper from the 303(d) List of pollutants of concern in the Bay (**page 30**).

These successes have made it possible for water quality managers to focus on the problems that remain (**page 59**). Four pollutants – mercury (total mercury and methylmercury), PCBs, dioxins, and exotic species – are classified as having the most severe impacts on Bay water quality because the entire Bay is considered impaired, and concentrations are well above established thresholds of concern. Mercury, PCBs, and dioxins pose health risks to humans that eat Bay sport fish and wildlife species at the top of the food web. The forecast for these pollutants is for slow progress toward recovery over the next 20 years. Exotic species have significantly altered the ecosystem, and can be expected to continue to do so in the absence of significant changes in management of the sources of these organisms.

Selenium, legacy pesticides, and PAHs are also of concern, because either the entire Bay or several Bay locations are included on the 303(d) List and concentrations are above established thresholds of concern (**page 59**). The outlook for these pollutants is a bit brighter, with a better chance of falling below risk thresholds in 20 years.

PBDEs, pyrethroids, sediment toxicity, and pollutant mixtures are classified as rising concerns because while water quality objectives have not yet been established for these pollutants in order to place them on the 303(d) List of impaired waters, there is a significant amount of concern about their impacts on the Bay (**page 59**). These concerns are growing, either due to increasing rates of input into the Bay or advances in understanding of their hazards. Trash discarded in Bay Area watersheds, creeks, and the Bay is another continuing concern due to potential adverse effects on humans and wildlife (**page 71**).

In the past few years, the attention of managers has shifted toward implementation of provisions that were included in the original CWA, but were not previously enforced. The CWA calls for the development of cleanup plans known as Total Maximum Daily Loads (TMDLs) for pollutants on the 303(d) List. A TMDL recently adopted for mercury and TMDLs in development for PCBs, dioxins, selenium, and legacy pesticides will address some of the most serious current threats to water quality. Implementation of the mercury TMDL is now beginning, with a major focus on the remaining challenge of reducing loads from urban runoff and other pathways that were not an emphasis in the first wave of implementation of the Clean Water Act of 1972.

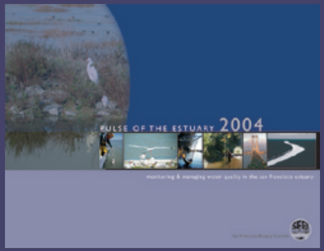
**Comments or questions regarding The Pulse or the Regional Monitoring Program can be addressed to Dr. Jay Davis, RMP Lead Scientist, (510) 746-7368, jay@sfei.org.**

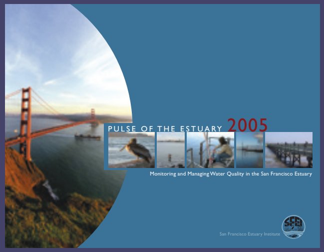
# Table of Contents



The Pulse of the Estuary is one of three types of RMP reporting products. The second, the Annual Monitoring Results, is distributed via the SFEI web site (www.sfei.org) and includes comprehensive data tables and charts of the most recent monitoring results. The third product is the RMP Technical Reports series. RMP Technical Reports each address a particular RMP study or topic relating to contamination of the Estuary. A list of all RMP reports is available at www.sfei.org/sfeireports.htm.

For PDF versions of the 2004, 2005 and 2006 Pulses, please go to www.sfei.org/rmp/pulse/index.html




# Management Update

## Recent developments in water quality management in the Estuary

# A Perspective on the 35th Anniversary of the Clean Water Act

Alexis Strauss
Director of the Water Division, Region IX
U.S. Environmental Protection Agency

Terms in Blue defined in Glossary on Inside Back Cover

The past 35 years of the Clean Water Act (CWA) have transformed our nation's commitment to solving our water pollution problems. Each decade's efforts brought forth essential progress, attributable to legislative mandates, federal and state investments in building programs, state and local focus on problem-solving, and an ever-growing public awareness, involvement, and advocacy.

In the 1970s a solid foundation was built nationally, establishing key elements which continue to influence the programs we carry out today.

- States were required to adopt water quality standards to protect all waters of the United States and their beneficial uses. This was a critical improvement over the 1965 Federal Water Pollution Control Act's limited focus on interstate and coastal waters.
- USEPA established nationally consistent, technology-based effluent limits for municipal and industrial dischargers. Perhaps the greatest pollution control advances were achieved by municipal wastewater treatment plants implementing full secondary treatment, funded in part by USEPA's Construction Grants Program. Some recalcitrant municipalities found the needed motivation through USEPA's municipal enforcement initiative of the time.
- The CWA required permits (still known as NPDES permits) for discharges to waters. The technology-based and water-quality-based limits in permits are the basis for ensuring compliance and protecting receiving waters.

In the 1980s USEPA and the states added other areas of emphasis, as the federal NPDES Program was gradually delegated to the states. The 1987 CWA Amendments enabled Indian Tribes to receive grant funds, and develop

The Bay Bridge. Photograph by Jay Davis.

and implement their own CWA programs under a similar delegation process. USEPA's Pretreatment Program was launched with state and local governments to control industrial discharges at their source. This remains one of the most technically complex and successful pollution-control programs being operated by local governments. The San Francisco Bay Regional Water Quality Control Board's pretreatment order, driven by the late Teng Wu, covered all Bay Area treatment plants; early leaders included East Bay Municipal Utility District, Palo Alto, Sunnyvale, and the Union Sanitary District. Most importantly, across all aspects of the NPDES Program, a culture of compliance grew among regulated dischargers, which remains very much in evidence today.

In the 1990s investment and attention were shifted to the more elusive sources of pollution, through growth of the nonpoint source, stormwater, biosolids, and wetlands programs. However, as states' emphases diverged and staffing levels waxed and waned with economic cycles, some areas of pollution control programs languished. Citizen enforcement became more commonplace, perhaps best manifested by the challenges to states' slow adoption of the pollution-control budgets known as TMDLs, or total maximum daily loads. Other broader legal challenges, used more sparingly, questioned the adequacy of state NPDES programs overall.

Now, after 35 years of our collective experience implementing federal and state water pollution programs, our focus is both on maintaining the gains achieved, and addressing a worthy set of new challenges.

**Renewing drinking water and wastewater infrastructure of the past century.** Local and regional governments are facing significant costs in assessing, repairing, and renewing their infrastructure on a sustainable basis. USEPA continues to capitalize the State Revolving Funds, which offer below-market rates and 20 years or more to retire the debt, but smaller and rural systems often lack the technical, managerial, and financial wherewithal to upgrade these vital assets. Moreover, we have yet to provide basic drinking water and wastewater service in very neglected parts of the West, including on some Tribal lands, at the Mexican Border, and in the Pacific Island territories, which face disproportionate public health risks for lack of safe water. Within established urban areas, local governments still contend with the operational challenges of controlling stormwater infiltration and inflow into sewage collection systems in wet weather, and a diverse set of pollutants transported to rivers and the coastline by wet-and dry-weather flows.

**Restoring beneficial uses to polluted waters.** As our monitoring and assessment capability grows, we better understand the need to reduce stressors and pollutants, and search for effective ways to control both pollutants and pollution at all scales, from trash, to microscopic invasive organisms, everyday pharmaceuticals in wastewater, and atmospheric deposition, among many. The tools we have depended upon, such as solid research to establish water quality standards, are not yet sufficiently developed to apply to these 21st century problems. One of our foremost challenges, adequately controlling sources of pathogens, is being addressed through the state's coastal monitoring and adoption of pathogen TMDLs into urban discharge permits.

**Protecting wetlands and other aquatic resources.** Our patterns of population growth and changing land use are putting great pressure on the largely unmapped, uninventoried wetlands of the West. It is difficult to protect the varied wetlands absent a unified commitment by local, regional, and county governments to plan for areas of conservation, using easements and other tools, while facilitating housing, transportation, commercial and industrial development in other areas. In the Bay Area, various experts came together to produce the Habitat Goals Project, to serve as a tool to guide such decisions (www.sfei.org/sfbaygoals/). USEPA and the U.S. Army Corps of Engineers are working together in the wetlands permitting program to minimize the impacts of wetlands fill, and with the Regional Water Board and San Francisco Bay Conservation and Development Commission, to assure greater beneficial re-use of material dredged from San Francisco Bay and the Delta.

**Adapting to global climate change.** We are novices at anticipating the varied impacts of gradual sea-level rise (page 50), and changes to the frequency and intensity of precipitation in the West, although we recognize the particular vulnerability of the Pacific Island territories. At present, we are turning our attention to incorporating greater water and energy efficiency measures into our decisions and investments, recognizing that larger economic and other forces, such as optimal water pricing, will also drive better use, reuse, and recycling practices. Within our 800-person Regional USEPA office in San Francisco, we have increased our sustainable workplace practices, better measuring our footprint as we try to reduce our impacts.

**Renewing the Clean Water Act.** More than a decade has passed since Congress updated the statute, although every year states call attention to a need for greater federal support of CWA programs and infrastructure. Should any of the long-standing approaches be changed? Could a bipartisan consensus be reached? Absent new regulatory tools or legislative direction, a panoply of geographic, regional, and local partnerships has emerged to find common ground, and forge problem-solving directions. Citizen involvement has grown - from robust participation in local watershed groups, to coastal clean up days, to electoral support for environmental ballot measures.

Our experience to date very much informs the way forward, as we continue to focus attention on both the familiar issues of sustainable infrastructure, water conservation, and reducing pollution loads while we also step up to the challenge of new issues such as climate change and emerging contaminants.

# The History of Municipal Wastewater Treatment: 35 Years of POTWs Protecting the Bay

Fred Krieger (fkrieger@msn.com), consultant
Michele Plá, Bay Area Clean Water Agencies
Charles Weir, East Bay Dischargers Authority

## Highlights

*As the Bay Area population grew through the 1900s, Bay water quality suffered.*

*By the 1950s, many communities had built primary sewage treatment plants, but water quality problems persisted or became worse into the early 1970s.*

*California's Porter-Cologne Water Quality Control Act of 1969 and the federal Clean Water Act of 1972 together provided a major impetus to cleaning up San Francisco Bay. The Clean Water Act provided clear goals and over a billion dollars toward construction of Bay Area wastewater treatment facilities.*

*Beginning in the late 1960s and continuing through the 1980s, Bay Area communities built secondary or tertiary level treatment facilities and improved wastewater outfalls, while controlling industrial inflows.*

*The Bay Area population has continued to increase, but pollutant inputs to the Bay from publicly-owned treatment works (POTWs) have plummeted, in some cases by 99%.*

East Bay Municipal Utility District wastewater treatment plant. Photograph by Greg Keller.

Terms in **Blue** defined in Glossary on Inside Back Cover

Management Update

**Figure 1**
**The Strawberry Creek Outfall carried the University of California and City of Berkeley's wastes directly into the Bay, contributing to the "Big Stench."** A report (Hyde et al. 1941) pointed out the sludge bank to the right of the outlet.

# Introduction

In 1972, Congress passed the Federal Water Pollution Control Act Amendments. This Act, which later became known as the Clean Water Act, set in motion a nation-wide effort to clean up our waterways. In the 1970s and 1980s, in response to the Clean Water Act, cities and utility districts around the Bay completed a massive public works campaign that built sewage treatment facilities. In a short span of time, these new and upgraded publicly-owned treatment works (POTWs) dramatically reduced the amount of pollutants released to the Bay. In the following decades POTWs continued to decrease the quantities of pollutants discharged to the Bay even as the population increased. Future reductions of pollutant discharge from POTWs are unlikely to be as dramatic as those following the initial construction program and wastewater agencies increasingly focus on preventing pollutants from entering wastewater collection systems. Today, roughly $500 million per year is spent in operating the facilities. This ongoing public investment is essential to the health of the Bay.

# What The Bay Was Like – Pollution Problems

Bay Area residents are now accustomed to a Bay with no readily apparent water quality problems. Some problems remain, but the gross pollution of the mid-1900s is gone. Before cleanup efforts began, the Bay was plagued with poor water quality that frequently caused large die-offs of fish and threatened the health of swimmers and consumers of shellfish from the Bay. Key water quality issues of these early years are described below.

**"The Big Stench."** Until the first treatment facilities were built - mostly after 1950 – raw sewage entered the Bay via streams or sewers. A 1941 study reported "because of this bad practice the shores and shore waters of the East Bay cities have become obnoxiously and notoriously foul and an affront to civic pride and common decency" (Hyde 1941) (**Figure 1**).

**Low Dissolved Oxygen and High Biochemical Oxygen Demand.** Dissolved oxygen (DO) is vital to aquatic organisms. In 1969, researchers noted that there were significant dissolved oxygen depletions in the Lower South Bay and that oxygen concentrations in Coyote Creek (near Milpitas) sometimes fell to zero (Kaiser Engineers 1969). As late as 1975, the San Francisco Bay Regional Water Quality Control Board (Water Board) reported that, in the lower extremity of South San Francisco Bay, biochemical oxygen demand (BOD – a measure of organic waste that causes oxygen depletion) had been observed to be as high as 48 milligrams per liter (mg/L) (essentially that of partially treated wastewater), while DO had been as low as 0.7 mg/L. Such low oxygen levels preclude the survival of most fishes. The Basin Plan minimum is 5 mg/L.

**Shellfish Contamination.** A shellfish study in 1972 noted that the Bay was "ringed by numerous discharge points which daily spew forth millions of gallons of polluting effluent" (Breslaw 1972a). The same study found that 14 out of 16 shellfish beds exceeded bacteria standards, and detected *Salmonella* in two of them. The Bay's oysters once supported the most lucrative fishery in California and were made famous by the writer Jack London. But by 1940 (according to Breslaw (1972a)), the fishery was decimated as a result of bacterial contamination.

**Fish Kills.** In 1971, the State Water Resources Control Board sent a report to Governor Reagan and the Legislature (SWRCB 1971) stating that "toxic materials and nutrients are discharged in virtually all municipal and industrial wastewaters; these toxic materials and nutrients cause fish kills and excessive algae blooms, particularly in the nearshore areas." The report listed fish kills that had occurred between 1965 and 1970; several of those kills involved over 10,000 fish (**Figure 2**).

# Early Wastewater Treatment Facilities

Palo Alto began operating a primary treatment (**Sidebar, next page**) plant in 1934. This was the first treatment facility in the South Bay and perhaps in the Bay Area. Most communities constructed primary plants during the 1950s (**Table 1**).

In 1963, a report from UC Berkeley estimated that $200 million had been spent on wastewater treatment facilities since 1950 but noted that "the problem of

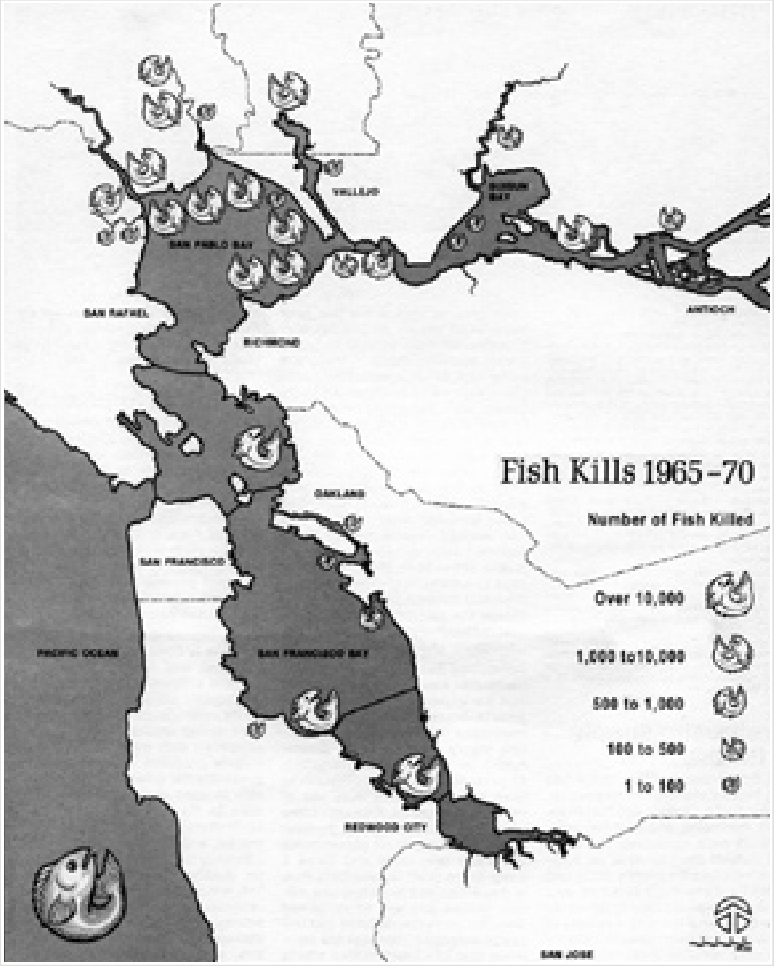



**Figure 2**

**In 1971, the State Water Resources Control Board sent a report (SWRCB 1971) to Governor Reagan and the State Legislature concluding that in spite of "great strides … the Bay water system continues to suffer marked deterioration in quality."** The report used graphics like the one above to illustrate the water quality problems and proposed an overall agency to construct and manage the needed treatment, reclamation, and disposal facilities.

pollution stubbornly defies solution" (Scott 1963). A few facilities, including those of San Jose/Santa Clara, Oro Loma, and Dublin-San Ramon, were providing secondary treatment (**Sidebar**) by the late 1960s. However, most secondary treatment facilities were not built until funds became available through the Clean Water Act. Many of the early and smaller facilities were eventually abandoned as flows were consolidated and treatment upgraded.

By the early 1970s, the total municipal and industrial wastewater flow to the Bay was 786 million gallons per day (mgd) (Breslaw 1972a). Municipal dischargers accounted for 452 mgd, or 58% of the total wastewater flow (the current municipal discharge volume to the Bay is approximately 617 mgd, an increase of 37%). A report on industrial waste discharges in the Bay Area, including the Sacramento/San Joaquin Delta, noted that most of the industrial inputs came from a few facilities: one paperboard mill in Antioch contributed 45% of the total industrial loading of BOD to the Bay and Delta and 20% of the suspended solids (Breslaw 1972b).

**Table 1.**
**Representative early primary treatment facilities on San Francisco Bay**

| Facility | Online |
|---|---|
| Palo Alto | 1934 |
| Petaluma (discharge to river) | 1938 |
| Central Contra Costa San. Dist. | 1948 |
| Oro Loma Sanitary District | 1950 |
| San Francisco–North Point | 1951 |
| East Bay Municipal Utility District | 1951 |
| Mountain View | 1951 |
| San Francisco–Southeast | 1952 |
| Hayward | 1954 |
| San Jose/Santa Clara | 1956 |
| Sunnyvale | 1956 |
| Los Altos | 1957 |

### Levels of Wastewater Treatment

**Primary Treatment.** The first stage of the wastewater treatment process where mechanical methods, such as filters and scrapers, are used to remove pollutants. Solid material in sewage also settles out in this process.

**Secondary Treatment.** The second stage of the wastewater treatment process (following primary treatment) involving the biological process of reducing organic matter through bacterial metabolism. This process generally removes 80 to 90 percent of the BOD and suspended solids.

**Tertiary Treatment.** The third stage of wastewater treatment removes nutrients or other pollutants that resist conventional treatment practices. This can be accomplished by a variety of biological, physical, and chemical separation processes.

# Laws, Regulations, and Planning

For over a century, federal and state legislators have attempted to put controls on water pollution. Major progress did not occur, however, until the Clean Water Act introduced mandated treatment levels and substantial federal funding. Key steps in the history of regulation of Bay water quality are described below.

**1899. Refuse Act.** Federal water quality protection efforts began in 1899 with the Refuse Act, which prohibited the discharge or deposit of "any refuse of any kind" into any navigable water of the United States. Sewage and street runoff were excluded from the prohibition. This Act was resurrected in 1970 by President Nixon, who directed the newly created Environmental Protection Agency (USEPA) to implement a permit program based on this law.

**1948. Water Pollution Control. Federal Authority Given to Surgeon General.** The first federal Water Pollution Control Act authorized the Surgeon General to prepare plans and programs to eliminate or reduce the pollution of interstate waters and tributaries.

**1949. Dickey Water Pollution Act in California. State and Regional Water Boards Formed.** The Dickey Water Pollution Act created the California State Water Pollution Control Board (later the State Water Quality Control Board) to set statewide policy and to coordinate with other agencies. The Act also established the nine regional boards that still exist today. Staffing was an issue: in 1958, the San Francisco Regional Water Board had five employees and a budget of approximately $74,000 (Scott 1963).

**1956 to the 1960s. Some Federal Funding for Treatment Plants.** Federal amendments to the Water Pollution Control Law in 1956 started a grant program for sewage treatment plants which continued into the 1960s, providing up to 30 percent of facility cost or $250,000, whichever was less. Although this level of funding now seems trivial, Palo Alto's first treatment plant only cost about $63,000 to construct. The 1956 amendments also strengthened enforcement provisions by providing for an abatement suit where health was being endangered.

**1965. State Water Pollution Control Law.** Water Quality Standards Developed. The State Water Quality Control Board (the predecessor of the current State Water Resources Control Board) adopted water quality objectives in 1967. Also in 1967, the Central Valley and San Francisco Regional Water Boards identified a list of beneficial uses for the waters within the Bay-Delta system (Kaiser Engineers 1969). These beneficial uses included the familiar ones still part of the current San Francisco Basin Plan, such as domestic water supply, recreation (whole body water contact and limited contact), fish and wildlife propagation and sustenance, and esthetic appeal.

The 1965 law also directed the State Water Board to assess the feasibility of a comprehensive, multi-purpose waste collection and disposal system that would serve the entire area. This plan, completed in 1969, recommended eventual (2005) implementation of a Reclamation-Marine Disposal System, with most Bay Area treated waste flows directed to the ocean along with a substantial reclamation component (Kaiser Engineers 1969).

**1969. Porter-Cologne Act: Key State Law.** The Porter-Cologne Act of 1969 rewrote existing state law and created the state requirements in their current form. The Act introduced waste discharge requirements as part of a permit system for all discharges with the potential to adversely affect water bodies.

**1972. Clean Water Act: The Modern Era.** The Federal Water Pollution Control Law Amendments of 1972, Public Law 92-500, later known as the Clean Water Act, built on the experiences of California and other states that had pre-existing permit programs. Key components included a permitting program called the National Pollutant Discharge Elimination System (NPDES). This program implemented "technology-based" minimum limits applicable to all dischargers as well as "water quality-based" limitations to address local water quality standards.

The mandatory technology-based standards avoided the problem of previous state-based permitting efforts, which had floundered because of the difficulty of linking water quality problems to specific dischargers. Thus, all POTWs were required to achieve secondary treatment as defined in the regulations, regardless of which dischargers were most responsible for the problems.

Probably most importantly, the Clean Water Act brought with it substantial funding; by 1987, the Clean Water Act had provided $1.2 billion in federal funds to the Bay Area (U.S. 1987). This initial grant funding was supplemented by requirements that wastewater agencies develop equitable self-funding revenue programs to pay for the local share of construction and ongoing operation and maintenance costs.

**1975. Updated Basin Plans, Increased Enforcement.** In 1972, the Regional Water Boards began an effort to update the Basin Plans and bring them into compliance with the Clean Water Act (SFBRWQCB 1975). These plans were due in July 1975 and constituted the first Basin Plans as we currently know them. They were intended to create a management scheme for the next 20 to 30 years, with revisions "at least annually" (**Figure 3**). Regional Water Board enforcement efforts also increased. For example, the San Francisco Board issued 113 "cease and desist" orders in year 1976-77, a third of all such orders issued in the state (SWRCB 1978).

**1986. Congressional Hearings: "Contamination of the San Francisco Bay."** In 1986, a congressional subcommittee met in San Francisco to discuss pollution of the Bay. Representative George Miller presided and cited the "large number of recent reports, some public and some not yet released, which document that the future of San Francisco Bay is threatened."

Don Anderson, Chairman of the San Francisco Regional Water Board, testified that the Bay had gone from 80 percent noncompliance with bacteria standards in the early 1960s to 80 percent compliance 20 years later. He also pointed to improvements in fisheries, including the re-establishment of the commercial bait fishery for native Bay shrimp. A representative from the POTWs, Walter Bishop of East Bay Municipal Utility District, testified that municipal dischargers had realized a 96% reduction in the quantity of heavy metals released to the Bay. Representatives of environmental groups continued to point to POTWs and industry as significant sources of metals and other toxic pollutants but also identified hazardous waste sites and stormwater as contributors to Bay pollution.

**Subsequent Developments.** Both the Porter-Cologne Act and the Clean Water Act have been amended since their original passage, but the basic framework they developed remains in place. One significant change came in 1987, when the Clean Water Act was amended to include specific requirements for the control of municipal and industrial stormwater.

## What Was Built

Although limited federal funding was available up through the 1960s, the Clean Water Act provided a huge jump in funding beginning in 1973. The Federal Construction Grant Program became the largest nonmilitary public works program since the Interstate Highway System. Bay Area facilities were early and active participants in the Program, which originally provided 75% of project costs from federal sources, with the state contributing another 12.5%. The local share of project costs was thus only 12.5%, which made the construction of wastewater facilities viable for most communities. California was the first state in which USEPA authorized state management of the Program. Governor Jerry Brown promoted an accelerated construction program, and between 1975 and 1977, the state processed over $2 billion in grant applications from municipalities.

The federal contribution to facility construction costs was reduced to 55 percent in 1981, and the Construction Grant Program was eventually phased out in 1982. The federal Water Quality Act of 1987 authorized the current State Revolving Fund program, which continues to provide low-interest loans for wastewater facilities.

The federal and state funding helped implement Water Board plans, which included consolidating facilities; upgrading secondary treatment facilities for all


**Figure 3**
**In the 1975 San Francisco Basin Plan, the Water Board opted for regional consolidation of wastewater treatment facilities.** The first Basin Plan in 1969 proposed taking almost all treated wastewater to the ocean in combination with eventual reclamation of much of the flow (Kaiser Engineers 1969). The Kaiser authors stated that "for any given level of wastewater treatment the effects would be less adverse for discharge to the ocean than they would be for discharge in a confined "estuary". In the 1975 Basin Plan, as shown in the figure, the Board proposed a lower-cost, moderate consolidation program that would also be compatible with future reclamation. Upgrades to at least secondary treatment were also part of the plan.

POTWs; and nutrient removal or bans on dry-weather discharges to critical waterways. By the time the Basin Plan was approved in 1975, many of the needed secondary facilities were under construction or completed. The implementation schedule in the 1975 Basin Plan provided for all treatment plants to be under construction by 1977, with completion no later than 1980.

In 1987, the Water Board reported that between 1960 and 1985, over $3 billion had been spent in the Bay Area to upgrade and construct wastewater treatment plants and to move outfalls into deeper water. By 1987, all but one POTW discharging to the Bay were providing at least secondary treatment. Between 1960 and 1985, the number of POTWs in the region had been reduced from 82 to 58 (with 46 discharging directly or indirectly into the Bay) to allow for better treatment and more dilution in the Bay. Many of those phased out were inefficient and inadequate in terms of capacity and effluent quality.

## Population Growth and Changes in Wastewater Volume

From 1955 to 1975, wastewater flows increased faster than population growth in the wastewater service areas. It is not clear why this occurred, but perhaps postwar industrialization increased flows into the collection systems. However, after 1975, this pattern changed, and population increased faster than wastewater flows due to water conservation and the closure or relocation of heavy water-using industries, such as canneries. California's 1987-1992 drought, in particular, spurred water conservation practices (**Figure 4**).

The Bay Area is highly rated for water conservation practices. The State Water Code requires the preparation of Urban Water Management Plans that must include conservation measures. Ongoing conservation efforts have reduced the volume of flows to treatment plants, although influent pollutant concentrations to POTWs may increase.

## What Was Achieved

Within 15 years of the adoption of the Clean Water Act in 1972, Bay water quality had improved substantially. This improvement included greatly reduced discharge of the "conventional pollutants" total suspended solids (TSS) and BOD, as well as of bacteria. Discharges of toxic metals were also reduced during this period, since they are often associated with TSS. However, determining exact reductions of some pollutants is difficult because of imprecise analytical methods in the early years. Acceptable data for metals in effluents were not generally available until the mid-1980s, and data on long-term trends are limited to certain metals.

### Conventional Pollutants

In 1987, the Water Board completed a comprehensive review of the status of pollutant inputs to the Bay based on 30 years of TSS and BOD data. These two pollutants are important because USEPA uses them to define the expected performance of secondary treatment facilities. The Water Board review included loadings from 1955 to 1985 and documented major reductions in the Bay (SFBRWQCB 1987). These early data have been extended to bring the record up to date (**Figure 5**). The decreases in

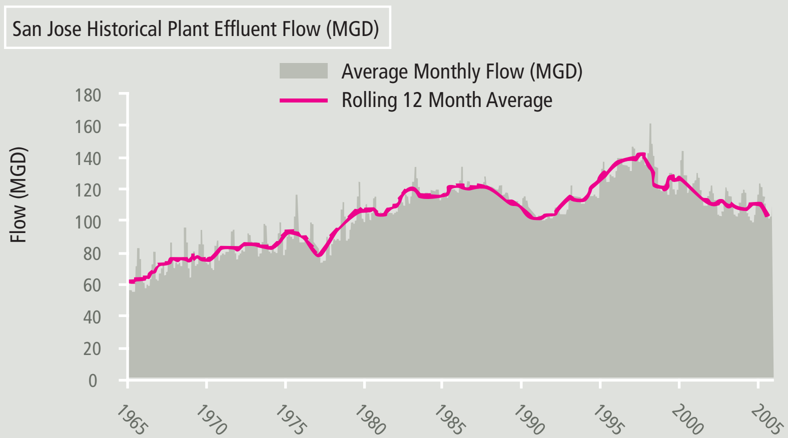



**Figure 4**
**The service area population of the San Jose/Santa Clara Wastewater Treatment Plant is one of the fastest-growing in the state, but wastewater flows have decreased in recent years.** Flows decreased during California's 1987-1992 drought and then again beginning about 1998. Local communities and the Santa Clara Valley Water District have aggressive water conservation programs. One goal of these plans is to decrease the volume of treated freshwater discharged to South Bay salt marshes during the drier months in order to protect endangered species.

TSS and BOD loading resulted from upgrading primary treatment facilities to secondary or, in some cases, tertiary (**Sidebar, page 9**). Palo Alto and Sunnyvale upgraded to tertiary treatment in 1978; San Jose/Santa Clara in 1979. Currently, more than 30 percent of Bay Area flows receive advanced (tertiary) treatment.

The Lower South Bay has been particularly challenged, because these waters are shallow and poorly flushed. Before the Clean Water Act and the Construction Grant Program, this segment of the Bay was the most stressed. However, by 1985, dischargers to this region had decreased their BOD loading by 99% even though wastewater flows had more than doubled since 1955 (**Figure 6**).

## Toxic Pollutants

Even more striking than BOD and TSS reductions are the decreases in toxic metals loading to the Bay that occurred after facility construction began. Because of shortcomings in early chemical analysis techniques, long-term assessment of changes in toxic concentrations is limited to a few metals. As one example, the East Bay Municipal Utility District (EBMUD) began partial secondary treatment in mid-1977 and had full secondary in operation by late 1978. The new facilities reduced metals loadings by over 70% percent. In the following years, pretreatment controls (limits on industrial and commercial releases into the sewage collection system) resulted in additional substantial reductions (**Figure 7**).

It is particularly remarkable that significant reductions in metal loadings continued after the major construction era ended in about 1985. More extensive data on metal loadings are available beginning in the mid-1980s and illustrate the effectiveness of the pretreatment controls imposed by wastewater agencies on industrial and commercial facilities discharging into the collection systems (**Figures 8 and 9**). The intent of these controls is to ensure that commercial and industrial discharges do not disrupt treatment systems or pass through pollutants that may cause water quality problems. In addition, the agencies implemented pollution prevention programs targeting the general public and businesses.

## Effluent Toxicity Reduced

POTWs conduct toxicity tests on their effluents, in which test organisms are exposed to effluent. There are two types of tests: 1) acute, which measures mortality of the test organisms; and 2) chronic, which measures impacts on reproduction or growth. Tests are conducted using the most sensitive organisms possible, which are usually juvenile fish, shellfish, crustaceans, or algae. POTW effluents rarely show any acute toxicity, and with only a few exceptions, there is very little chronic toxicity in POTW effluents (SFBRWQCB 2007).

## Bacteria

Disinfection with chlorine became common with the first primary treatment facilities constructed in the 1950s. However, chlorination is less effective on only partially-treated wastewater, since suspended solids can "shelter" bacteria that can remain viable. The implementation of full secondary treatment at all facilities and additional tertiary treatment at some facilities meant that chlorination became increasingly effective.

By the late 1970s, the Water Board had noted the rapid changes in Bay water quality: "the bacteriological conditions in the Bay improved 5 to 16 fold between 1973 and 1976, and swimming is now safe in most areas of the Bay during summer" (SFBRWQCB 1987) (**Figure 10**).

# The Benefits

By 1987, improvements in Bay water quality were dramatic (**Sidebar page 16**).

Despite these improvements, Luoma and Cloern (1982) noted that some major problems continued into the 1980s. Localized instances of accumulation of toxic metals and trace organics in the food web equalled those anywhere in the world. Indications of physiological stress in animals contaminated with these pollutants had also been observed. Later studies concluded that clam reproduction was significantly reduced due to metal contamination through the 1980s and into the 1990s.

Improvement in Bay water quality continued in the 1980s and 1990s. Metals concentrations in the food web declined considerably during this period in response to load reductions, and recent findings indicate that they are no longer affecting clam populations in the Bay (**page 61**).

Although loadings of many pollutants from POTWs have declined substantially since the 1950s, some other sources have not been reduced in a comparable manner. These sources include urban runoff and the legacy pollutants in Bay sediments such as mercury left over from gold-mining days. Water quality problems in the Bay also persist (**page 59**).

# What's Next For POTWs?

Beginning in the late 1960s, the clean water agencies of the Bay Area dramatically reduced pollutant loading to the Bay. Ongoing monitoring, however, has identified new problems that need to be addressed.

Total BOD and TSS Loading to the Bay

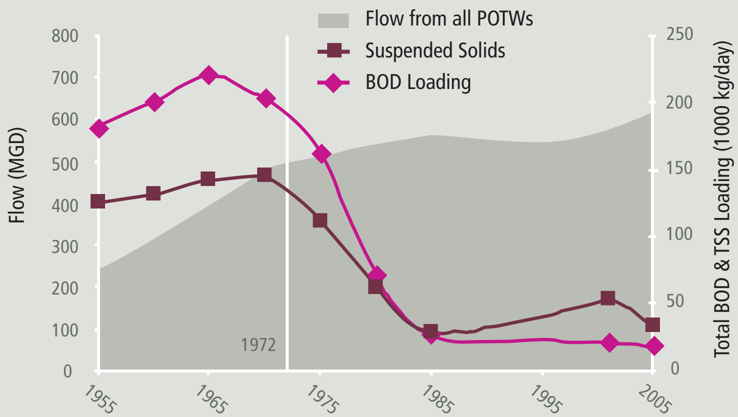



**Figure 5**

**Funding for the construction of treatment facilities provided by the 1972 Clean Water Act produced a sharp drop in pollutants released to the Bay.** By 1985, Bay Area POTWs had reduced TSS by 80% and BOD by 88% from the high values recorded two decades earlier, while the service area population increased by 52% over the same period.

Lower South Bay Segment

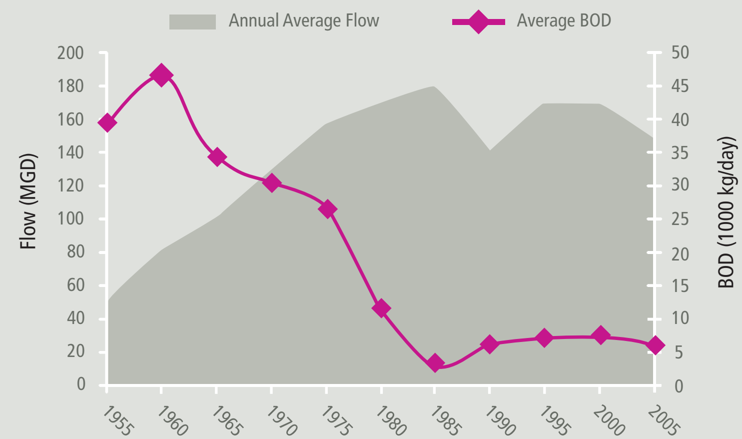
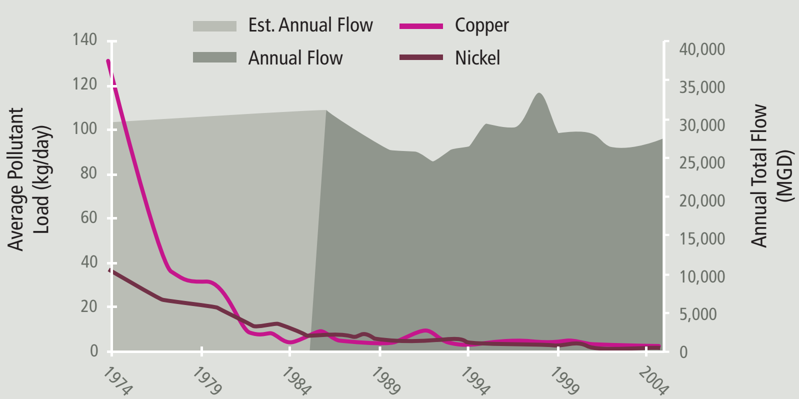



**Figure 6**

**An extraordinary decrease in pollutant inputs has benefited the highly-stressed Lower South Bay.** The 1955 to 1985 effluent BOD data were collected by the Water Board and combined with recent data from dischargers.

Copper and Nickel Loading From EBMUD




Footnote: This graph combines historical data from EBMUD with subsequent data (1986–2005) from the Regional Water Board (Lam 2007). (Flow between 1974 and 1986 is estimated as a straight line)

**Figure 7**

**Discharges of metals declined even more than BOD and TSS.** The extraordinary reduction in East Bay Municipal Utility District (EBMUD) copper and nickel loadings resulted from the construction of secondary treatment facilities followed by aggressive pretreatment and pollution prevention programs.

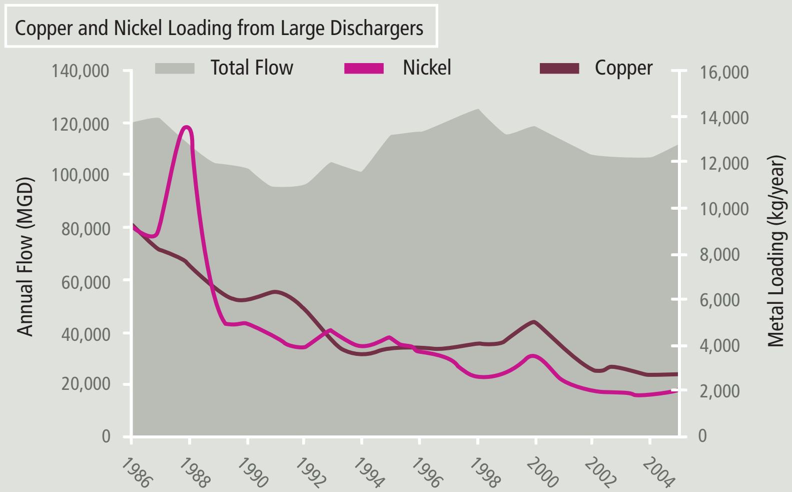



**Figure 8**

**Due to pretreatment and pollution prevention programs, metal loadings continued to decrease after treatment plant construction was completed.** Four treatment plants (San Jose/Santa Clara, San Francisco, EBMUD, and Central Contra Costa Sanitary District) discharge 53% of the total volume of treated wastewater flowing to the Bay. Most reductions in metal loadings likely took place when the secondary or tertiary facilities were built in the 1960s and 70s. Nevertheless, loadings of copper and nickel have decreased by an additional 75% since 1986.

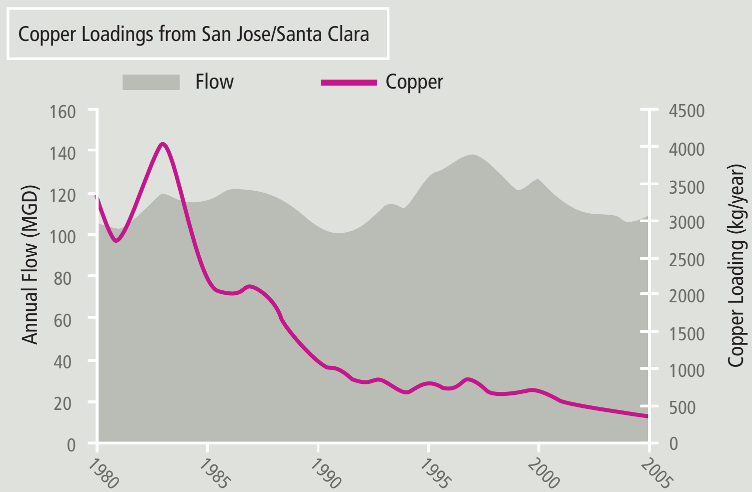



**Figure 9**

**The San Jose/Santa Clara POTW was able to reduce its copper loading to the Bay by over 90% in the period after its tertiary treatment facility came online in 1979.** The Bay Area has benefited from copper pollution prevention programs, including legislation that prompted the California Department of Pesticide Regulation (DPR) to prohibit copper-based root control products in 1995, an action that was urged by POTW groups such as BACWA and Tri-TAC. In addition, the San Jose/Santa Clara facility has implemented an In-plant Copper Reduction and Treatment Processes Optimization Program.

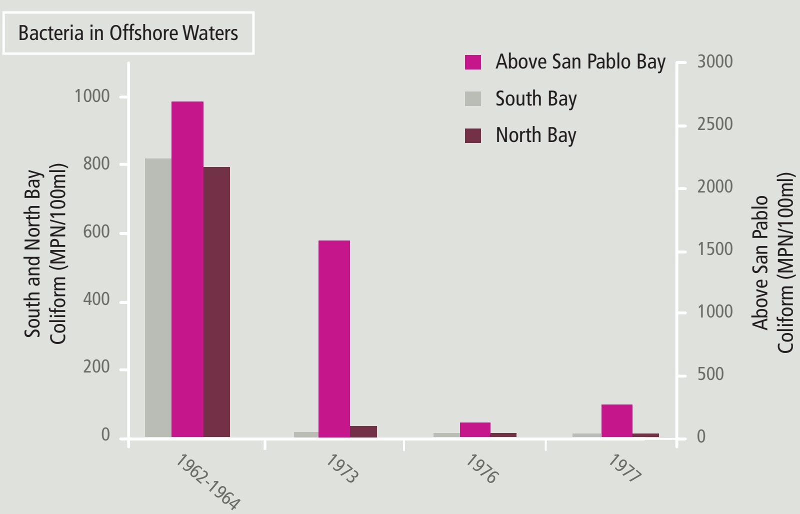



**Figure 10**

**Data collected by the Water Board in 1977 showed rapid improvement in the bacterial quality of Bay water.** Coliform bacteria are typically used as indicators of the possible presence of pathogenic (disease-causing) organisms in wastewater or the Bay.

Clean Water Act Section 305(b) requires each state to prepare a biennial report on the condition of waters within state boundaries. Referencing the Regional Monitoring Program, California's 2006 report (California Water Boards 2006) indicates that the two main contaminants of concern in the Bay are mercury and polychlorinated biphenyls (PCBs). The report also mentions the toxicity of storm-water runoff and contaminated sediments as concerns, as well as emerging contaminants such as polybrominated diphenyl ethers (PBDEs). Mercury and PCBs are targeted by cleanup plans known as total maximum daily loads (TMDLs) (**Sidebar, next page**).

## New Challenges

**Compounds of Potential Concern.** Water quality managers are concerned about newly emerging pollutants termed Compounds of Potential Concern (CPC). CPCs include PBDEs, endocrine disruptors, and residues from medicines and personal care products. Many of these are present in POTW wastewater, generally at low levels, and may present a threat to Bay water quality, as they do to many water bodies in the country and the industrialized world.

### Improved Water Quality

In a 1987 report, the Water Board summarized the benefits and changes in pollutant loadings to the Bay.

- Swimming is now safe in most areas of the Bay during summer.
- Bay water quality has improved to the point that public harvesting of shellfish in San Mateo County was approved in 1982 (for the first time in 50 years) and subsequently in 1983 and 1985.
- As a result of a dramatic improvement in DO south of Dumbarton Bridge and the low salinity regime created by tertiary effluents, Bay shrimp (*Crangon franciscorum*) were once again abundant re-establishing a viable commercial bait fishery) (SFBRWQCB 1987).

Our ability to detect these emerging pollutants in the waters of the Bay and in other waterways is partly due to improved technical capabilities. Unfortunately, very little is known about these substances, and we are far from clearly understanding the level of risk associated with them. At this point, Bay Area clean water agencies are attempting to reduce these compounds in their discharges through public education campaigns and other pollution prevention efforts. CPCs are a societal issue, and preventing them from becoming the legacy pollutants of the future will take the concerted effort of all stakeholders.

**Reclamation.** Some POTWs currently reclaim some wastewater for reuse for irrigation or other needs. The need for wastewater reclamation will likely increase in the future due to constraints on water supplies. Most reclamation uses require higher levels of treatment.

**Hydromodification.** Hydromodification refers to changes in a waterway resulting either in an increase or decrease in the volume of water flowing or changes in the shape of the waterway. Hydromodification has greatly impacted the Bay in the past. In the future, global climate change will likely result in additional hydromodification that could affect POTWs. Sea level rise (**page 50**) will increase the infiltration of salt water into some low-lying collection system sewers and thereby increase wastewater salinity, making reclamation less viable and possibly harming the biological processes involved in the wastewater treatment process. The dynamics of the Bay will also change in ways that are difficult to forecast, due to changes in patterns of runoff from the Sierra Nevada, changes in tidal action due to the increased depth of the Bay, and other factors.

**Chlorination.** The potential need to address byproducts resulting from chlorination and dechlorination of wastewater is another water quality concern. Recent work has shown chlorination reacts with pollutants such as some pharmaceutical residues and may increase the toxicity of some of these compounds. In the 1980s, the Water Board and POTWs conducted studies on the Bay and concluded that alternative limits for bacteria could reduce the amount of chlorine used for disinfection of effluent. These alternative limits allowed many agencies to reduce their chlorine use by 50% or more. This cooperative effort between the Water Board and POTWs greatly reduced the quantity of disinfection byproducts that reach the Bay.

**Infrastructure Replacement.** Much of the existing wastewater infrastructure was constructed in the 1970s and is now reaching the point that replacement and upgrades to meet new requirements are beginning to occur. One of the major responsibilities of POTWs is to collect revenues adequate to fund future replacements. Bay Area agencies are in the process of spending hundreds of millions of dollars in the next 5 to 10 years to meet this challenge.

## Ongoing Efforts by POTWs

The daily activities at POTWs are directed at achieving continued reductions in pollutant loading to the Bay.

**Enforcement of "Local Limits."** Every reissued POTW discharge permit requires a reassessment of the numeric discharge limitations that are imposed by the POTWs on industries and other regulated facilities discharging to the municipal collection system. Municipal agencies monitor dischargers as well as influent to the treatment plant to track performance.

**Implementation of Pollutant Minimization Programs.** The permits also require specific control efforts to address pollutants suspected of exceeding limitations.

**Optimizing treatment.** Treatment plant operators continue to look for opportunities to fine-tune treatment operations and improve the performance of existing facilities.

**Support for research and monitoring.** Wastewater agencies are major supporters of the Regional Monitoring Program and financially support the collection of technical data for TMDL development for the Bay. The agencies also contribute to national efforts such as the Water Environment Research Foundation, whose work includes a current research project on Estimation of Mercury Bioaccumulation Potential from Wastewater Treatment Plants in Receiving Waters. This research will attempt to clarify the relationship between mercury levels in wastewater treatment plant discharges and mercury accumulation in the food web.

## Recent Initiatives

While the initial pollution control efforts in the 1970s and 1980s focused on building treatment facilities, many of the newer programs are directed at controlling original sources, that is, keeping problem pollutants out of wastewater collection systems altogether.

**Collecting Discarded Medicines.** In May 2006, the Bay Area Pollution Prevention Group, composed mostly of Bay Area clean water agencies, collected 3,500 pounds of unused or expired medications at 32 locations. Some agencies currently provide ongoing collection services or facilities.

**Controlling Dental Mercury.** In 2004, San Francisco began the state's first regulatory program to capture the mercury released during the preparation, placement, and removal of silver fillings. Other Bay Area agencies have now implemented or are planning to implement similar efforts.

**Comprehensive Pollution Prevention.** Palo Alto's Regional Water Quality Control Plant has developed a Clean Bay Campaign targeting pollution prevention efforts not only for toxic wastes going into the collection system but also pollutants, such as pesticides used on lawns, which are carried into the Bay by stormwater.

**Thermometer Exchange, Fluorescent Light Bulb Recycling, and Related Efforts.** Many wastewater agencies provide facilities and financial support for recycling household products containing mercury and other toxics (see http://www.baywise.info/).

Wastewater agencies view their primary mission as protecting the Bay and will continue to implement the programs needed to achieve this goal.

### TMDLs and POTWs

TMDLs are being prepared for both mercury and PCBs. The TMDLs are required for polluted waterways and result in the allocation of "safe" loadings of pollutants to dischargers and other sources as a means of bringing pollutant concentrations to acceptable levels. Currently, mercury loading to the Bay from POTWs is estimated at 17 kg/yr, which is 1.4% of the estimated 1,200 kg/yr that enters the Bay. The TMDL calls for a reduction of the POTW load to 11 kg/yr. For comparison, urban storm water is estimated to contribute about 160 kg/yr (about 13% of the total load) and will receive an allocation of 82 kg/yr.

For PCBs, the estimate of current total loading is 84 kg/year, with 2.3 kg/year coming from POTWs (about 2.7%) and 40 kg/year from urban runoff (about 48%). As currently planned, both POTWs and urban runoff management agencies will need to reduce loading to 2.0 kg/yr. Pollution prevention efforts, rather than additional treatment, will likely be used to achieve the necessary load reductions from POTWs.

# Refinery Environmental Performance Over the Past 20 Years

Bridgette DeShields
ARCADIS BBL

Kevin Buchan
Western States Petroleum Association

## Highlights

*Five oil refineries are currently active in the Bay Area*

*Over the last 20 years, the refineries have invested nearly $100 million in capital improvements, including installing additional treatment technologies to protect water quality in the Bay*

*Water conservation efforts, as well as the use of reclaimed water in refinery processes, resulted in a significant reduction of wastewater effluent flows*

*Selenium Removal Plants (SRPs) within the refineries have been quite successful in achieving reductions, with the most recent studies indicating an average 66% reduction in selenium discharge*

Chevron Refinery. Photo by Linda Wanczyk.

Terms in Blue defined in Glossary on Inside Back Cover

# Wastewater Treatment by Bay Area Refineries

Petroleum refineries have been operating in the San Francisco Bay Area for over 100 years, with beginnings as early as 1896. In 1987, there were six oil refineries operating in the San Francisco region. With the closure of Pacific Refinery in the mid-1990s, five refineries currently remain: Chevron in Richmond, Conoco-Phillips in Rodeo, Shell and Tesoro in Martinez, and Valero in Benicia (**Figure 1**).

The Bay Area refineries treat their wastewater prior to discharge using multiple treatment technologies. These sophisticated treatment plants are capable of removing a wide array of contaminants that include petroleum hydrocarbons, metals, toxics, and other materials so their discharges are in compliance with environmental regulations. Wastewater prior to treatment may include water from the refining process, including desalting, distillation, or cracking units, as well as wastewater from utilities such as boilers and cooling towers.

Prior to the 1960s, simple treatment technologies such as gravity separators were employed to treat wastewater. As time progressed, additional and more


Map courtesy of Google Earth™

**Figure 1**
**Locations of Bay Area refineries.**

sophisticated control technologies were developed and implemented by the refineries in order to meet increasingly more stringent environmental regulations. Around the mid 1960s and 1970s, the addition of aeration ponds marked a milestone of significant upgrades that has had a continued progression into present day refinery environmental controls.

## Influence of the Clean Water Act

Water quality regulations have set the standard for environmental performance. The Clean Water Act (CWA) became law on October 18, 1972 and required the implementation of best practicable technology (BPT) for the discharger community. The CWA resulted in the promulgation of new standards and prompted the reduction of contaminant concentrations in wastewater to meet revised permit limits. This included efforts by the refineries to reduce raw water intake and use reclaimed water sources instead; it also resulted in a more lengthy and complicated regulatory permitting and compliance reporting process. As part of the CWA, the USEPA proposed BPT guidelines for refineries circa 1974 and several upgrades were installed in the years that followed. These upgrades included adding or expanding aeration ponds, installing deep water outfalls with diffusers, adding secondary treatment, and installing clarification basins. More recently, total maximum daily load (TMDL) programs have been developed and implemented as required under the CWA, and have resulted in additional wastewater discharge regulation. TMDLs are expected to call for additional treatment to reduce effluent loadings from the refineries, although most of the TMDLs remaining to be developed will address historic legacy pollutants where the refineries contribute a small fraction of the overall loading to the Bay.

In addition to the treatment changes required by the CWA, corporate environmental accountability and awareness has become commonplace. Oil companies and other large industries have established environmental compliance metrics across their operations with annual goals reflecting increasing environmental stewardship and focus. Conducting business with an emphasis on protecting the environment has become a standard for all refineries in and outside the region. Furthermore, the refining industry commonly partners with regulatory agencies and community groups, and implements continuous improvement programs in order to conserve water, preserve natural resources, minimize waste streams, and enhance processes for the benefit of the environment.

## Reduction in Flow

The refineries have implemented several measures in recent years, including improvements and upgrades to their wastewater treatment plants, that have resulted in significant improvements in effluent quality and reductions in discharge flow.

Twenty years ago, the six operating refineries discharged approximately 30 million gallons per day (MGD) of treated effluent (based on data from 1984 to 1986; Gunther et al. 1987). Water conservation efforts, as well as the use of reclaimed water in refinery processes, resulted in significant flow reductions at one of the refineries, which decreased its flows from nearly 20 million to less than 8 million MGD (**Figure 2**).

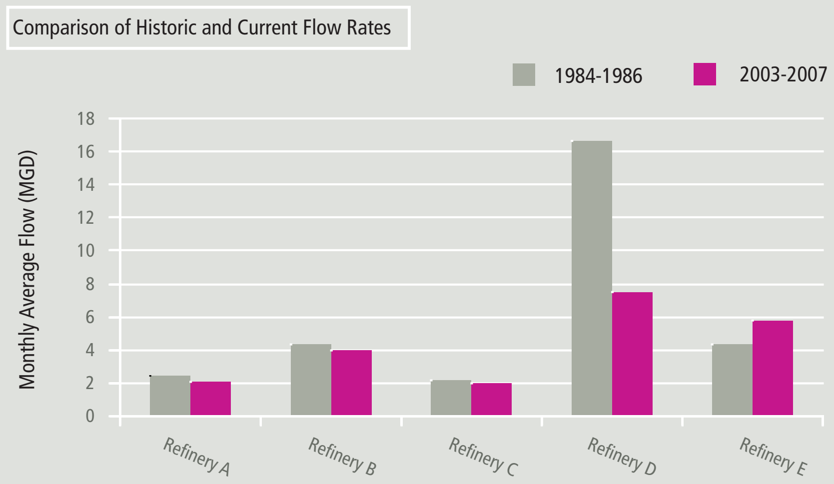



**Figure 2**
**Water conservation efforts, as well as the use of reclaimed water in refinery processes, resulted in a significant reduction of flows from the refinery with the largest wastewater discharge.**

# Selenium

Studies in the 1980s indicated that refineries were one of the primary sources of selenium. Twenty years ago, selenium loads to the Bay from refineries in aggregate were approximately 15 pounds per day, which accounted for nearly 25% of all selenium loads to the Bay. Concentrations of selenium in refinery effluents ranged from 18 to 173 micrograms per liter (ug/L).

The refineries worked with the San Francisco Bay Regional Water Quality Control Board (Water Board) in an effort to reduce their loads of selenium to the Bay. In the late 1990s, several of the Bay Area refineries installed Selenium Removal Plants (SRPs) to achieve reductions. SRPs use chemical precipitation to remove selenium. Precipitated selenium-containing solids are dewatered in a filter press and sent to a permitted waste management facility. Treated effluent from the SRP may receive further treatment prior to discharge. The refineries have been quite successful in achieving reductions, with the most recent studies indicating an average 66% reduction in selenium discharge (Cutter and Cutter 2004) (**Figure 3**) and a remarkable 92% average reduction in the amount of selenite (the form of selenium of greatest concern).

The refinery SRPs not only reduced mass loading but also achieved concentration reductions as well. Refinery effluent selenium concentrations are well below 50 ug/L on a consistent basis (**Figure 4**).

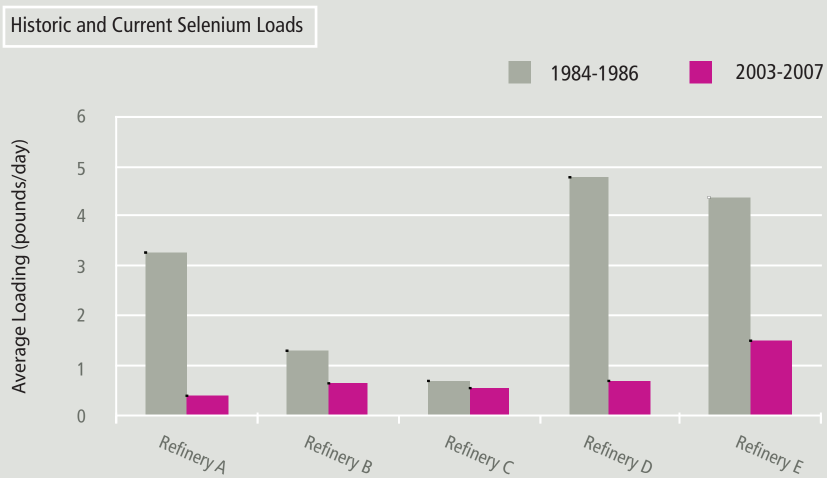
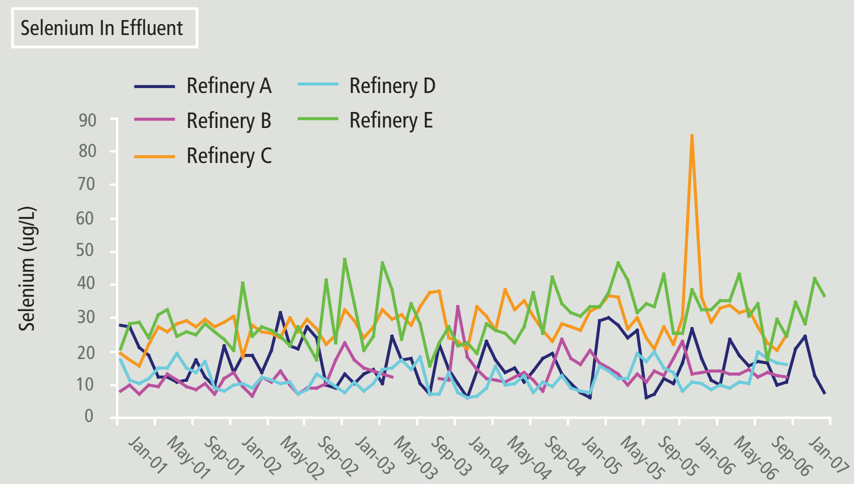



**Figure 3**
**In the late 1990s, several of the Bay Area refineries installed Selenium Removal Plants (SRPs) to achieve reductions.** The refineries have been quite successful in achieving reductions, with the most recent studies indicating an average 66% reduction in selenium discharge.




Footnote: Graph based on monthly averages.

**Figure 4**
**The refinery Selenium Removal Plants not only reduced mass loading but also achieved concentration reductions as well.** Refinery effluent selenium concentrations are well below 50 ug/L on a consistent basis.

## Effluent Toxicity

A comprehensive effluent toxicity monitoring program was initiated in the mid-1980s with refineries and other Bay Area dischargers being required to characterize toxicity in their effluents for a variety of aquatic species. Effluent toxicity tests required for compliance from that point forward included both weekly acute toxicity tests and less frequent chronic tests. The refineries implemented additional treatment technologies to achieve lower effluent toxicity and maintain compliance with the more stringent limits.

## Investments in Water Quality

Over the last 20 years, the refineries have invested nearly $100 million in capital improvements, including installing additional treatment technologies to improve effluent quality and protect water quality in the Bay. In the 1980s, many refineries installed aggressive biological treatment for their wastewater. Biological treatment typically takes place in ponds or other units with aeration and some refineries utilize oxidation ponds. Dissolved nitrogen floatation (DNF) units are also used to remove suspended oil solids.

Improvements to effluent treatment have included complete treatment plant rebuilds and upgrades by some refineries, addition of end-of-pipe disinfection, additional pretreatment steps, and upgrades of oil/water separators.

## Current and Upcoming Challenges

The challenges that the refineries expect to face in the coming years related to maintaining compliance with water quality goals and requirements include the following:

- The increasing water shortage crisis in California will put significant additional emphasis on water conservation and reuse over the next 20 years.
- The current schedule for TMDLs is a challenge. The State Water Resources Control Board water quality implementation plan allows interim limits for TMDL pollutants until May 2010. Unless TMDLs are adopted and incorporated into permits before then, all NPDES dischargers will be required to meet very stringent final water quality limits regardless of their loading contribution to the Bay and despite any relief a pending TMDL would provide.
- More stringent standards may require new control technologies that are currently not available.

## Summary

The refineries have achieved measurable success over the last 20 years to improve effluent quality, reduce discharge flows and contaminant loading, increase water reuse, and overall contribute toward improving water quality in the Bay. Their commitment to corporate environmental stewardship and continuous improvement demonstrates their dedication to doing their part to protect Bay water quality.

# The Regulatory State of the Bay: A Status and Trends Review

Thomas Mumley
Assistant Executive Officer
San Francisco Bay Regional Water Quality Control Board

## Highlights

*Water quality management in the Bay is at a historic turning point, with recent and pending regulatory actions to resolve impairment due to metals and persistent legacy pollutants*

*The Basin Plan establishes water quality standards for the Bay which are the beneficial uses of the ecosystem, water quality objectives to protect beneficial uses, and an antidegradation policy*

*The first Basin Plan in 1975 laid the foundation for current water quality standards and implementation actions*

*Basin Plans have evolved since 1975 in response to changes in Bay water quality, advances in scientific understanding of the ecosystem, and management and regulatory actions*

Sailing on San Francisco Bay, view of Alcatraz in background. Photograph by Jay Davis.

Terms in **Blue** defined in Glossary on Inside Back Cover



# A Watershed Mark in Managing Bay Water Quality

We are on the verge of reaching a watershed mark in resolving San Francisco Bay water quality impairment issues. With recent and pending regulatory actions by the San Francisco Bay Regional Water Quality Control Board (Water Board), we will be able to apply more attention to implementation actions to attain and maintain water quality standards while we continue to seek resolution of remaining water quality impairment issues. Most importantly, we can now apply more attention to emerging pollutants, such as bromine- and chlorine-based flame retardants and fluorine-based stain repellants. A review of regulatory drivers over the past three decades and the emergence and maturation of the RMP provides a context for describing accomplishments to date and why the current regulatory status merits designation as a watershed mark.

Let's start with a review of recent actions (**Table 1**). The State Water Resources Control Board (State Water Board) delisted (removed from the State's 303(d) List of impaired waters) all Bay segments for diazinon in 2006. The Water Board adopted site-specific water quality objectives for cyanide throughout the Bay in December 2006 and for copper in the Bay segments north of the Dumbarton Bridge in June 2007. The Water Board will consider adopting a PCBs TMDL for all San Francisco Bay segments by the end of 2007 and will consider recommending delisting San Francisco Bay segments for nickel in early 2008. Meanwhile, a selenium TMDL project for the north Bay segments is underway with anticipated action by the Water Board by the end of 2009 or early in 2010, and project plans are being developed to resolve impairment of the Bay by legacy pesticides and dioxins. The status of these and other TMDL projects can be tracked by checking the Water Board's web page at http://www.waterboards.ca.gov/sanfranciscobay/tmdlmain.htm

**Table 1**
**The current regulatory status of pollutants of concern in San Francisco Bay.**

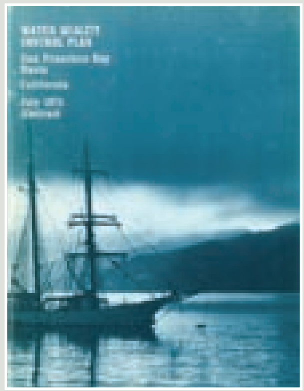
| Pollutant | Regulatory Status |
|---|---|
| Copper | South SF Bay site-specific objectives (SSOs) in 2002<br>Removed from 303(d) List in 2002<br>SSOs for rest of Bay in 2007 |
| Cyanide | Site-specific objectives in 2006 |
| Diazinon | Removed from 303(d) List in 2006 |
| Dioxins / Furans | TMDL project plan being developed |
| Legacy Pesticides (Chlordane, Dieldrin, and DDT) | TMDL project plan being developed |
| Mercury | Initial TMDL in 2004<br>Revised TMDL and site-specific objectives in 2006 |
| Nickel | South SF Bay site-specific objectives (SSOs) in 2002<br>South SF Bay removed from 303(d) list in 2002<br>Other segments attain CTR objectives and delisting will be recommended in 2008 |
| PCBs | Water Board will consider TMDL in 2007 |
| Selenium | TMDL project started in 2007<br>Water Board consideration in 2009/2010 |

# Water Quality Standards

The focus of the RMP has been on metals, toxicity, and persistent bioaccumulative toxics (e.g., PCBs), so this retrospective review will be limited to these pollutants and regulatory drivers and actions relevant to them. Of particular note is that many of the drivers and actions from the past are still relevant today. An early and very significant regulatory action was adoption of a "Statement of Policy with respect to Maintaining High Quality of Waters in California" by the State Water Board in October 1968 (Resolution 68-16). This Resolution requires the continued maintenance of existing high quality waters, but provides conditions under which a change in water quality is allowable. A change must provide maximum benefit to the people of the State and not unreasonably affect present and anticipated potential beneficial uses of water. Resolution 68-16 serves as the State's antidegradation policy, which is a key component of the State's water quality standards.

The term water quality standards is often confused with or used interchangeably with the terms water quality objectives and water quality criteria. Although the terms are interrelated they are distinct. Water quality standards are collectively the beneficial uses of a water body, the water quality objectives (which can be numerical or narrative) established to protect the beneficial uses, and the antidegradation policy. "Water quality criteria" is a federal term that typically reflects a numerical value for a pollutant set by the US Environmental Protection Agency (USEPA) to protect aquatic life, wildlife, or human health. Water quality criteria are really just recommendations that are not binding until adopted by a state via a regulatory action or by USEPA if a state fails to adopt them or alternatives. The State's water quality standards are contained in and established via its Basin Plans or statewide plans. So in summary, State water quality objectives are usually based on federal water quality criteria, and water quality objectives are a component of water quality standards that also include beneficial uses and the antidegradation policy. With this background, we can now review the Basin Plan and key amendments that established water quality standards and associated implementation actions relevant to this retrospective.

## The First Basin Plan (1975)



The first complete Basin Plan was adopted by the Water Board in 1975. (There were interim versions in 1969, 1971, and 1973.) The 1975 Basin Plan designated the beneficial uses of all Bay waters and established a few numerical water quality objectives primarily for non-toxic substances (e.g., bacteria, dissolved oxygen). The main water quality concerns were expressed in findings that the dissolved oxygen levels in the Lower South Bay were depressed considerably below natural values, shellfish harvesting had been all but eliminated within all segments of the Bay, and recreational uses along the Bayshore of the San Francisco Peninsula were not permitted during portions of the year due to bacterial contamination from untreated wet weather discharges. In response to these concerns, the prime focus of the 1975 Basin Plan was on wastewater (sewage) discharges.

The 1975 Basin Plan included implementation provisions based on the water quality standards discussed above and secondary treatment regulations that were an outgrowth of the 1972 federal Clean Water Act (CWA). These included a call for biochemical oxygen demand (BOD), suspended solids, and coliform bacteria discharge limits, and most importantly, prohibitions of wastewater discharges that did not receive a minimum initial dilution of 10 to 1 or to confined water areas or their immediate tributaries. Exceptions to the prohibition would be considered under limited conditions, such as where an equivalent level of environmental protection could be achieved by alternative means (i.e., advanced treatment). Although the primary target of these provisions was based on what are commonly referred to as conventional pollutants (BOD, suspended solids, and bacteria), the resulting reductions in conventional pollutant loads also resulted in significant reductions of toxic pollutant loads.

The 1975 Basin Plan did include some toxic pollutant provisions. Most relevant to this retrospective is that it established a narrative water quality objective for toxics:

> "No toxic or other deleterious substances shall be present in receiving waters in concentrations or quantities which will cause deleterious effects on aquatic biota, wildlife, or waterfowl or which render any of these unfit for human consumption either at levels created in receiving waters or as a result of biological concentration."

> This is the narrative objective that is often stated as "there shall be no toxics in toxic amounts".

Although the focus of the 1975 Basin Plan was on wastewater, it did have the foresight to recognize that correction and prevention of adverse water quality impacts would require a broader approach. The abstract of the 1975 Basin Plan contained the following profound statement:

> "Future attempts to control water quality must be based on factors more omnibus than consideration of municipal and industrial wastewater treatment alone. Basin planning differs from similar studies of the past in that an attempt is made to assess a much broader range of man's activities."

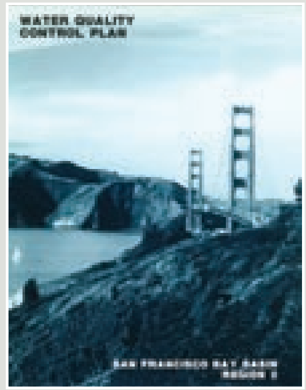
Accordingly, the 1975 Basin Plan included forward-thinking statements and calls for action regarding construction activities, urban runoff management, and dredging and disposal of dredged material.

## The 1982 Basin Plan


The 1982 Basin Plan primarily refined the 1975 Basin Plan provisions. It continued to focus attention on wastewater discharges and started to attend to toxic pollutants. An implementation provision was added calling for narrative wastewater discharge permit limitations to minimize discharge of conservative toxic substances through the application of a source control program and adequate wastewater treatment. The 1982 Basin Plan also set forth numeric wastewater discharge limits for a set of toxic metals and cyanide.

In the spirit of looking beyond wastewater, the 1982 Basin Plan recognized increasing sediment loads from local tributaries associated with increase in urban land while projecting a decline in Central Valley sediment input. Consequently, the 1982 Basin Plan established an aggressive construction-site erosion and sediment control program. Also, although it did not establish regulatory requirements, it recognized that urban runoff was becoming an increasingly larger share of the total load of pollutants to the Bay and recommended initiation of an urban runoff monitoring program and prevention and treatment measures.

## The 1986 Basin Plan




The 1986 Basin Plan brought enhanced attention to toxic pollutants. First and foremost it included new water quality objectives for metals in the Bay based on federal water quality criteria promulgated in the early 1980s. However, the objectives were not adopted for Lower South Bay; the Basin Plan noted the unique conditions of this area and called for site-specific objectives. Another exception was federal water quality criteria for copper were not adopted for any of the Bay segments due to uncertainties surrounding attainment and whether the criteria were relevant to San Francisco Bay.

The 1986 Basin Plan included a new set of wastewater effluent limits for metals and cyanide to implement the new objectives. The limits were based on a 10-to-1 dilution credit for deep water discharges and zero dilution credit for shallow water dischargers that had been granted exceptions to the prohibition of discharges that did not receive a minimum initial dilution of 10 to 1. The new water quality objectives and associated limits were very controversial since there were very few Bay water quality data upon which to judge attainment. Even though we had seen significant reductions in wastewater loadings of conventional pollutants (i.e., BOD, suspended solids, and pathogens), compliance with metals limits would possibly require costly additional treatment.

A substantial addition to the Basin Plan in 1986 was an urban runoff management program that required monitoring of dry weather and wet weather urban runoff pollutant concentrations and loads; evaluation of existing control measures and identification and evaluation of additional control measures; and a program for the implementation of additional controls and ongoing monitoring to evaluate their effectiveness. The program was founded on the recognition that control of just wastewater would not attain water quality objectives particularly in Lower South Bay where municipalities were already implementing advanced wastewater treatment. Note that this call for urban runoff management preceded the 1990 NPDES permit requirements for stormwater that were an outgrowth of the 1987 revisions to the federal CWA.

The 1986 Basin Plan was the Water Board's first effort to set water quality standards for specific toxic pollutants (i.e., metals). It was a very contentious endeavor mainly due to limited information on Bay water quality and whether it was getting better or worse after substantial investments (over $3 billion) in wastewater treatment systems. Meanwhile, growing urban runoff pollutant loads needed to be controlled, but we didn't know what or how much control was needed. We needed a regional monitoring program!

*The RMP was created in April 1992 by Water Board Resolution 92-043, which required wastewater, urban runoff, and dredging dischargers to report on far-field effects of discharges*

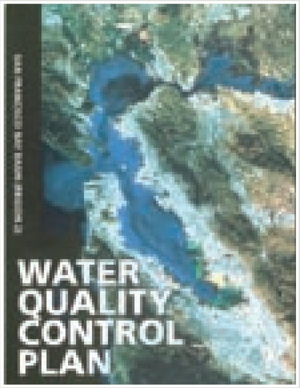
## The Inception of Regional Monitoring

The 1986 Basin Plan set the stage for the Regional Monitoring Program (RMP). Then in 1989 the Water Board contracted with Dr. Russ Flegal at UC Santa Cruz to monitor metals in the Bay using ultra-clean techniques, and for the first time, we had a complete data set of metals levels throughout the Bay to compare to water quality objectives. This unprecedented effort was the precursor of the RMP and demonstrated that cost-effective regional monitoring that addresses management questions was possible.

The Bay Protection and Toxics Cleanup (BPTC) Program was also created in 1989 via legislation, which provided cause and resources to monitor toxics in sediments throughout the Bay and also served as a RMP building block. The BPTC Program came with four major goals that are still relevant today: (1) protect existing and future beneficial uses of bay and estuarine waters; (2) identify and characterize toxic hot spots; (3) plan for the prevention and control of further pollution at toxic hot spots; and (4) develop plans for remedial actions of existing toxic hot spots and prevent the creation of new toxic hot spots. The BPTC Program legislation also called for development of narrative and numeric sediment quality objectives for the protection of enclosed bays and estuaries, an effort that is still ongoing.

The RMP was created in April 1992 by Water Board Resolution 92-043, which required wastewater, urban runoff, and dredging dischargers to report on far-field effects of discharges. The Water Board strongly encouraged a region-wide collaboration in lieu of individual monitoring. At the same time the San Francisco Estuary Project was building its Comprehensive Conservation and Management Plan (adopted in 1993) that included a Regional Monitoring Strategy and recognized the emerging San Francisco Estuary Institute (SFEI) as the science steward of the Estuary. Consequently, SFEI was strategically poised to coordinate a regional monitoring program.

## The 1995 Basin Plan




The next sustained revisions to the Basin Plan came in 1995. A significant change was that the narrative toxicity water quality objective was split into three separate narrative objectives: one for bioaccumulation, one for population and community ecology, and one for toxicity. The 1995 Basin Plan maintained 1986 water quality objectives, and maintained the associated effluent limits for metals and cyanide but allowed for consideration of alternate limits based on site-specific objectives. Additionally, with increasing emphasis on urban runoff, the urban runoff management program was revised and expanded to reflect progress to date and the 1990 NPDES stormwater permit regulations. A new policy for consideration of numerical effluent limitations in stormwater permits was also added. The 1995 Basin Plan also included significant revisions to the Water Board's dredging and disposal of dredged sediment program that included recognition of the emerging Long Term Management Strategy for dredged material. It included a suite of dredging-related policies that encompassed the need for monitoring and testing guidelines, dredging windows, in-Bay disposal restrictions, and encouraged land and ocean disposal alternatives.

## The California Toxics Rule

There was a 1991 Basin Plan that was not approved since it was based on the Bays and Estuaries Plan adopted by the State Water Board earlier in 1991. The Plan included water quality objectives for all toxic pollutants for which USEPA had established water quality criteria, but the Plan was later voided by a state judge on procedural grounds. However, federal law (the CWA) requires states to have water quality standards for all pollutants for which USEPA has established water quality criteria. Consequently, USEPA promulgated the California Toxics Rule (CTR) in 2000 that made federal water quality criteria legally applicable to California waters (i.e., equivalent to water quality objectives). The exception was where water quality objectives already existed, specifically the water quality objectives for metals in the Bay adopted via the 1986 Basin Plan. However, the CTR did apply to South San Francisco Bay since, as noted above, the 1986 Basin Plan water quality objectives were not applicable there, and the CTR set a Bay-wide numerical standard (objective) for copper since the 1986 Basin Plan had not.

The State Water Board adopted the Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California in 2000 subsequent to the CTR. The Policy is the State Implementation Plan (SIP) for the CTR and contains implementation provisions for NPDES permits that set a statewide approach that superseded the numerical limits established in earlier Basin Plans. The SIP also set procedures for developing site-specific water quality objectives, which were consistent with the earlier Basin Plans' calls for site-specific objectives.

## Basin Plan Amendments in 2004 and 2005

There were two more sets of general Basin Plan amendments relevant to this review of regulatory trends, which were mainly regulatory and non-regulatory clean up actions. A result of the CTR and SIP was that some water quality objectives for the Lower South Bay were different than those for all the other Bay segments, and some Basin Plan implementation provisions were obsolete. A main difference was that CTR criteria for most metals were set as dissolved concentrations in water whereas all Basin Plan objectives were set for total (particulate and dissolved) levels. There was also a lot of dialogue in the Basin Plan that reflected historical implementation that was no longer relevant due to the CTR and SIP.

Basin Plan amendments in 2004 vacated the 1986 Basin Plan water quality objectives (for total metals) that had been recognized by the CTR and replaced them with the CTR (dissolved metals) objectives. An exception was the Basin Plan mercury objective which was sustained because the CTR criterion for mercury was not considered protective of wildlife. Wastewater discharge implementation requirements were also made consistent with the SIP, which included eliminating the specified metals discharge limits from the 1986 Basin Plan.

Basin Plan amendments in 2005 were non-regulatory amendments that eliminated outdated sections. They also created a numerical heading and subheading hierarchy that makes the Plan easier to read and access. Most importantly the revised format is internet friendly, and an electronic version with hyperlinks is accessible via the Water Board web site or via the direct link http://www.swrcb.ca.gov/rwqcb2/basinplan.htm.

## The Recent 303(d) List and TMDL Era

The evolution of the Basin Plan reflected the progression of water quality concerns from pathogens and depressed dissolved oxygen in the Bay to toxic pollutants and bioaccumulative substances. CWA Section 303(d), which requires states to identify water bodies that do not meet water quality standards, has been in effect since the 1970s. There were historical Bay impairment listings for pathogens and depressed dissolved oxygen that were removed with the emergence of upgraded wastewater treatment systems. However, the 303(d) List wasn't a critical factor in Bay regulatory actions until the 1990s. A big reason for this was the lack of reliable data upon which to assess attainment of standards, whether for direct assessment of beneficial uses, attainment of numerical or narrative water quality objectives, or degradation trends. That changed with the establishment of numeric water quality objectives for toxic pollutants and monitoring of toxic pollutants in the Bay via the RMP.

The first 303(d) listings of the Bay for toxic pollutants came in the early 1990s when all Bay segments were listed as impaired by metals in Bay waters. These metals listings were subsequently refined in 1996 to just copper, mercury, nickel, and selenium. Then in 1998, impairment listings for all Bay segments were added for persistent bioaccumulative toxics in Bay fish: PCBs, dioxins and furans, and the legacy organochlorine pesticides chlordane, DDT, and dieldrin. The Bay was also listed in 1998 for the organophosphate pesticide diazinon due to recurring episodic observations of toxicity in Bay waters following runoff events.

In addition to identifying impaired waters, CWA Section 303(d) requires states to establish Total Maximum Daily Loads (TMDLs) for pollutants that cause the impairments. TMDLs must be designed to attain applicable water quality standards. Water Board efforts began in the late 1990s following the impairment listings for specific toxic pollutants. The first successful resolutions of impairment listings started out as TMDL projects that morphed into site-specific water quality objectives projects for copper and nickel in Lower South Bay. The site-specific objectives were established via a Basin Plan amendment in April 2002 that subsequently led to delisting of Lower South Bay for copper and nickel. All the other Bay segments were also delisted for copper in 2002 since RMP data demonstrated attainment of the CTR copper objective.

The next response action was a Basin Plan Amendment in September 2004 that established a TMDL for mercury in all Bay segments. However, the State Water Board did not approve the TMDL and remanded it to the Water Board to resolve a number of issues. The most substantial water quality issue was whether the TMDL

Fishing pier in San Francisco. Photograph by Jay Davis.

would attain the Basin Plan mercury water quality objective. In response, the Water Board established a revised TMDL in August 2006 via a Basin Plan Amendment that also established new water quality objectives for mercury in fish in the Bay and eliminated the questionable water quality objective for mercury in water. The State Water Board approved the revised TMDL and new water quality objectives in July 2007.

## Back to the Future

This brings us back to the present and the future where we are approaching a watershed mark based on closure or closure-at-hand of Bay impairment listings with regulatory actions for metals and legacy persistent bioaccumulative toxics. The emerging drive and direction is to implement the regulatory actions and to better understand the "dirty sand box" in the Bay and sediment transport as it affects recovery from mercury, PCBs, legacy pesticides, and to some extent selenium. There is a very large mass of these chemicals in Bay sediments, based on large historical inputs from the Central Valley and local urban drainage. Inputs of these pollutants are now greatly reduced and further reductions will come at great costs, so we need an improved understanding of the Bay system to make sure we make smart decisions. Improved understanding of the ecosystem is also critical to resolving emerging concerns regarding pyrethroid insecticides, polycyclic aromatic hydrocarbons, bromine- and chlorine-based flame retardants, and fluorine-based stain repellants. We may be reaching a high mark in our pollution control efforts but our challenges are far from over.

New Bay Bridge construction.
Photograph by Nicole David.

# 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 (TMDL), to improve water quality. The list of impaired water bodies is revised periodically (typically every two years). The RMP is one of several programs 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: 1) development of a draft list by the San Francisco Bay Regional Board; 2) adoption by the State Water Board; and 3) approval by USEPA. The State Water Board compiled the most recent 303(d) List in 2006 following recommendations from the Regional Boards and information solicited from the public and other interested parties. The draft List was then revised based upon public comments. On October 25, 2006, the State Board adopted the California 2006 Revised 303(d) List. On November 30, 2006 US EPA gave partial approval to California's 2006 Section 303(d) List of Water Quality Limited Segments, with approval only withheld for areas outside of San Francisco Bay.

The primary pollutants/stressors for the Estuary and its major tributaries on the 2006 303(d) List include:

**Trace elements:** Mercury, Selenium, and Nickel

**Pesticides:** Dieldrin, Chlordane, and DDT

**Other chlorinated compounds:** PCBs, Dioxin and Furan Compounds

**Others:** Exotic species and polycyclic aromatic hydrocarbons (PAHs)

The current status of TMDL development is shown in **Table 1** on page 24.

**More information on the 303(d) List and TMDLs is available from the following web sites.**

**303(d) List for Region 2 (which includes the Bay)**
www.waterboards.ca.gov/sanfranciscobayTMDL/303dlist.htm

**TMDLs**
www.waterboards.ca.gov/sanfranciscobaytmdlmain.htm

www.epa.gov/owow/tmdl/

Port of San Francisco. Photograph by Jay Davis.

# RMP Committee Members and Participants

## RMP Committee Members

### RMP Steering Committee

Small POTWs, Ken Kaufman, South Bayside System Authority

Medium-sized POTWs, Daniel Tafolla, Vallejo Sanitation and Flood Control District

Large POTWs/BACWA, Chuck Weir, East Bay Dischargers Authority

Refineries, **Kevin Buchan**, Western States Petroleum Association

Industry, Dave Allen, USS-POSCO

Cooling Water, Steve Bauman, Mirant Delta LLC

Stormwater Agencies, Adam Olivieri, EOA, Inc.

Dredgers, Ellen Johnck, Bay Planning Coalition

San Francisco Bay Regional Water Quality Control Board, Tom Mumley

**RMP Steering Committee Chair in bold print**

### RMP Technical Review Committee

POTWs, Francois Rodigari, East Bay Municipal Utility District

South Bay Dischargers, Tom Hall, EOA Inc.

Refineries, Bridgette DeShields, ARCADIS BBL

Industry, Dave Allen, USS-POSCO

Stormwater Agencies, Chris Sommers, EOA, Inc.

Dredgers, John Prall, Port of Oakland

San Francisco Bay Regional Water Quality Control Board, Karen Taberski

U.S. EPA, Luisa Valiela

City of San Jose, **David Tucker**

City/County of San Francisco, Michael Kellogg

U.S. Army Corps of Engineers, Robert Lawrence

**RMP Technical Review Committee Chair in bold print**

## RMP Participants

### Municipal Dischargers

Burlingame Waste Water Treatment Plant

Central Contra Costa Sanitary District

Central Marin Sanitation Agency

City of Benicia

City of Calistoga

City of Palo Alto

City of Petaluma

City of Pinole/Hercules

City of Saint Helena

City and County of San Francisco

City of San Jose/Santa Clara

City of San Mateo

City of South San Francisco/ San Bruno

City of Sunnyvale

Delta Diablo Sanitation District

East Bay Dischargers Authority

East Bay Municipal Utility District

Fairfield-Suisun Sewer District

Las Gallinas Valley Sanitation District

Marin County Sanitary District #5, Tiburon

Millbrae Waste Water Treatment Plant

Mountain View Sanitary District

Napa Sanitation District

Novato Sanitation District

Rodeo Sanitary District

San Francisco International Airport

Sausalito/Marin City Sanitation District

Sewerage Agency of Southern Marin

Sonoma County Water Agency

South Bayside System Authority

Town of Yountville

Union Sanitary District

Vallejo Sanitation and Flood Control District

West County Agency

### Industrial Dischargers

C & H Sugar Company

Chevron Products Company

Conoco Phillips

Crockett Cogeneration

Dow Chemical Company

General Chemical Corporation

Rhodia, Inc.

Shell – Martinez Refining Company

Tesoro Golden Eagle Refinery

USS – POSCO Industries

Valero Refining Company

### Cooling Water

Mirant Delta LLC

### Stormwater

Alameda Countywide Clean Water Program

Caltrans

City and County of San Francisco

Contra Costa Clean Water Program

Fairfield-Suisun Urban Runoff Management Program

Marin County Stormwater Pollution Prevention Program

San Mateo Countywide Stormwater Pollution Prevention Program

Santa Clara Valley Urban Runoff Pollution Prevention Program

Vallejo Sanitation and Flood Control District

### Dredgers

Alameda Reuse & Redevelopment

Arques Shipyard & Marina

Caltrans

Chevron Richmond Long Wharf

City of Benicia

City of San Rafael

Clipper Yacht Club

Conoco Phillips

Corinthian Yacht Club

Paradise Cay Yacht Club

Port of Oakland

Port of San Francisco

Richmond Yacht Club

U.S. Army Corps of Engineers

Valero Refining Co.

Egrets at Arrowhead Marsh. Photograph by Linda Wanczyk.

# Status and Trends Update

## The latest findings from pollutant monitoring and research

# The Latest Monitoring Results

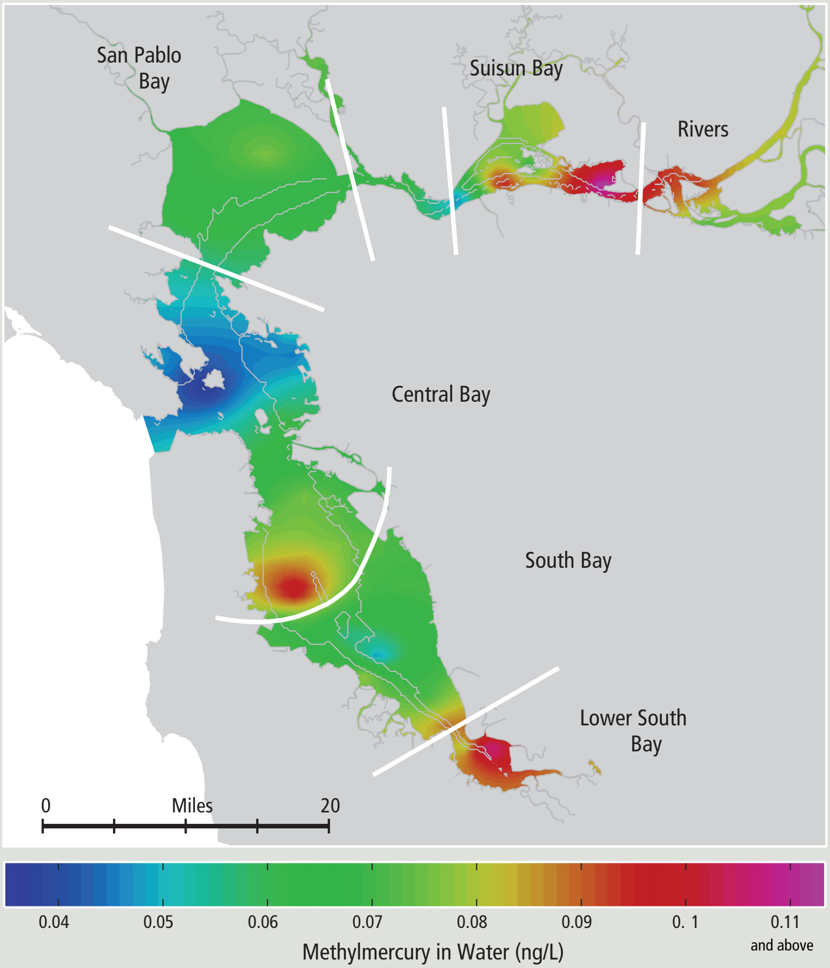
## Findings from RMP Monitoring and Other Bay Studies




RMP Sampling Cruise. Photograph by Susan Klosterhaus.

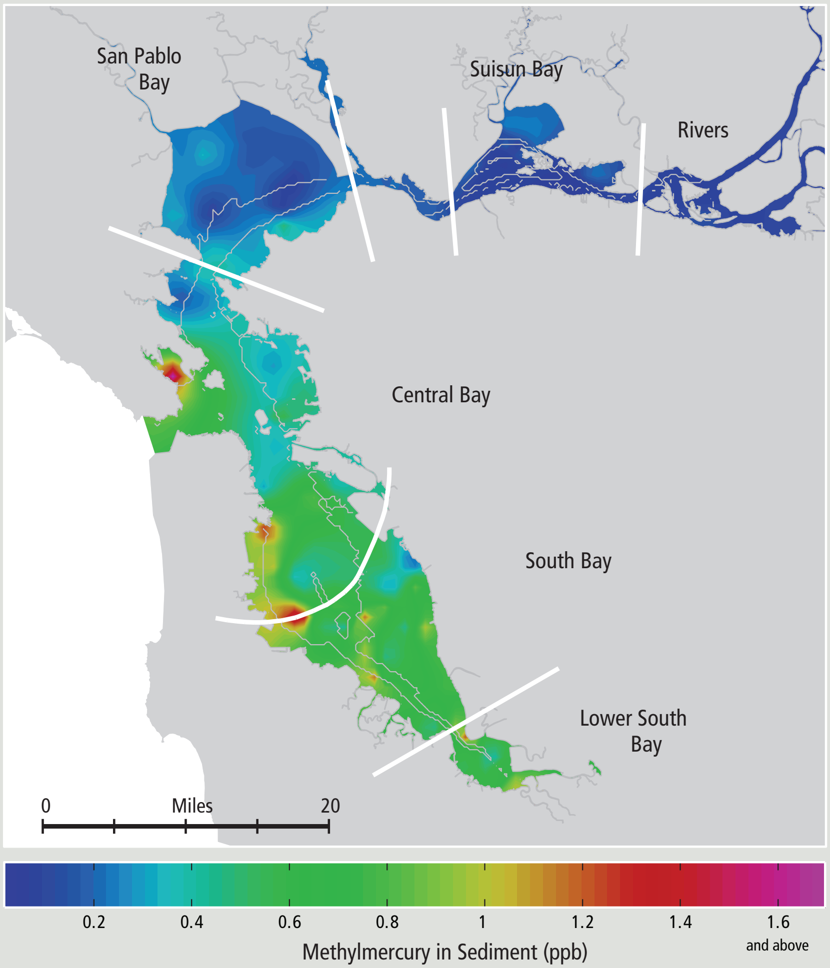
# Mercury

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 in some fish and wildlife species. The greatest health risks from mercury are generally faced by humans and wildlife that consume fish.



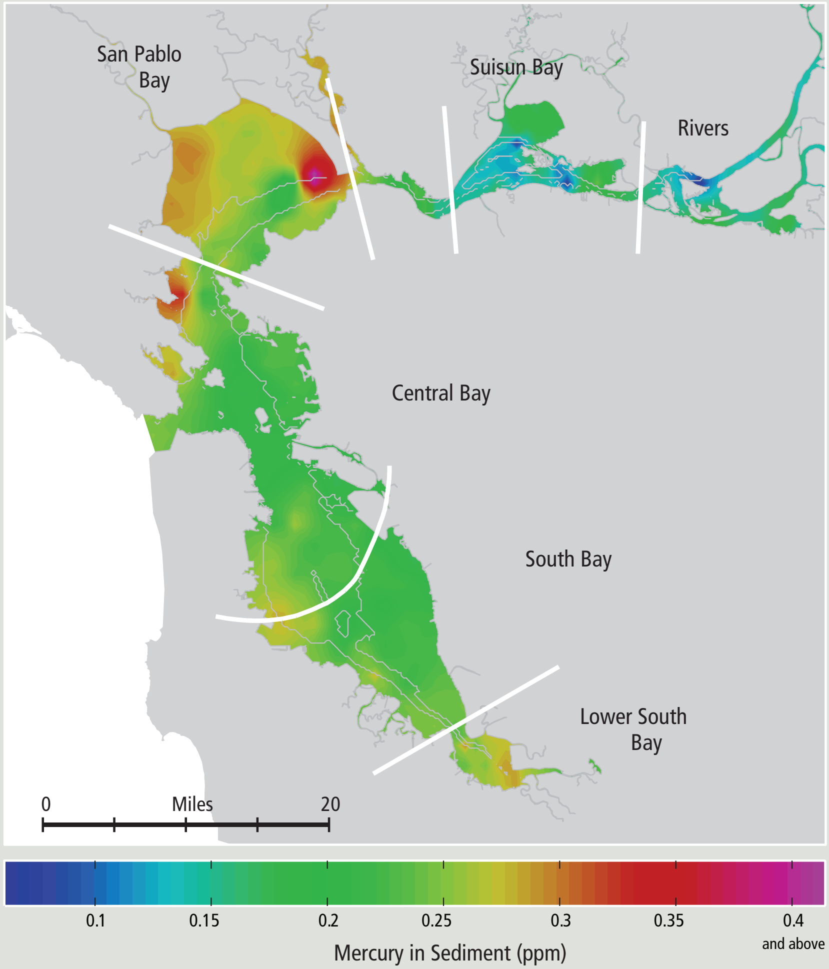

Footnote: Plot based on 31 RMP data points from 2006. Earlier years not included because a less sensitive method was employed. The maximum concentration was 0.13 ng/L in Lower South Bay. Data are for total methylmercury.

**Methylmercury in water, 2006.** Mercury exists in many different forms in the aquatic environment. Methylmercury 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 are variable in space and time. The RMP measures methylmercury in water and sediment of the Bay in order to better understand the sources of the methylmercury that are accumulated by Bay fish and wildlife. Lower South Bay had the highest average concentration (0.11 ng/L) of any segment. No regulatory guideline exists for methylmercury in water.




Footnote: Plot based on 233 RMP data points over a five-year period from 2002 – 2006. The maximum concentration was 2.4 ppb in Central Bay in 2002.

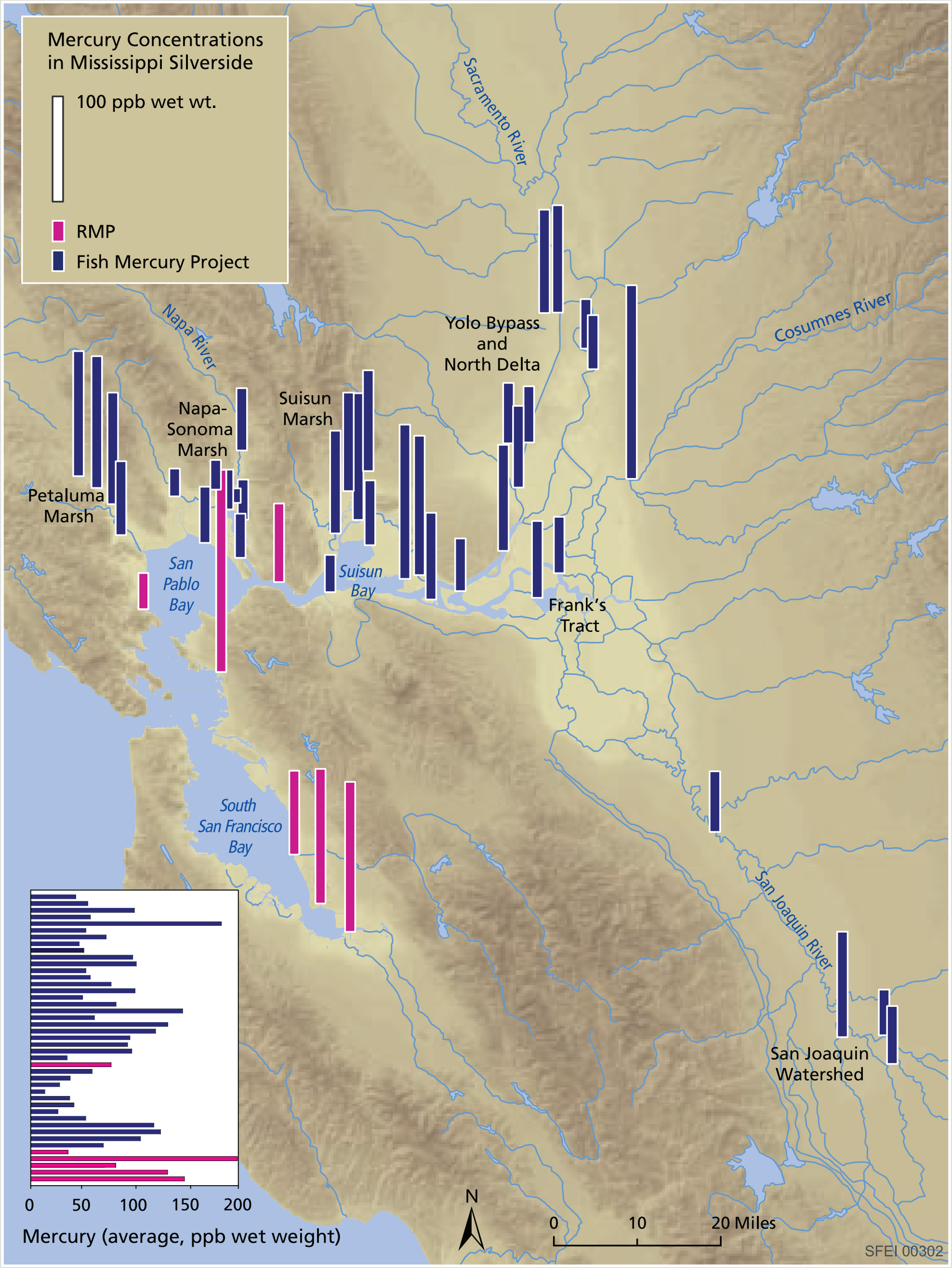
**Methylmercury in sediment, 2002 – 2006.** Mercury is converted to methylmercury primarily by bacteria in sediment. Methylmercury production can vary tremendously over small distances and over short time periods, so this figure should be viewed as the result of several snapshots of conditions in the Bay at the time of the surveys in the summers of 2002 – 2006. Concentrations of methylmercury in sediment from the Bay Bridge south have been consistently higher than those in the northern Estuary. No regulatory guideline exists for methylmercury in sediment.




Footnote: Plot based on 232 RMP data points over a five-year period from 2002 – 2006. The maximum concentration was 0.78 ppm near Mare Island in 2004.

**Total mercury in sediment, 2002 – 2006.** Methylmercury typically comprises only about 1% of the total of all forms of mercury in water or sediment. Total mercury is the summation of all forms of mercury in a sample, and is a rough index of the amount of mercury available for conversion into methylmercury. In contrast to methylmercury, total mercury concentrations in sediment have generally been highest in San Pablo Bay, moderate in the Central Bay, South Bay, and Lower South Bay, and lowest in Suisun Bay. The relatively high concentrations in San Pablo Bay may be related to deposits of debris from hydraulic gold mining in the Sierra that settled in this area in the 1800s. This area also tends to trap fine-grained sediment particles, which tend to have higher concentrations of mercury and other pollutants. A site near Mare Island in San Pablo Bay sampled in 2004 had the highest concentration by far (0.78 ppm).

Richard Looker and Paul Salop collecting a sediment sample. Photograph by Nicole David.



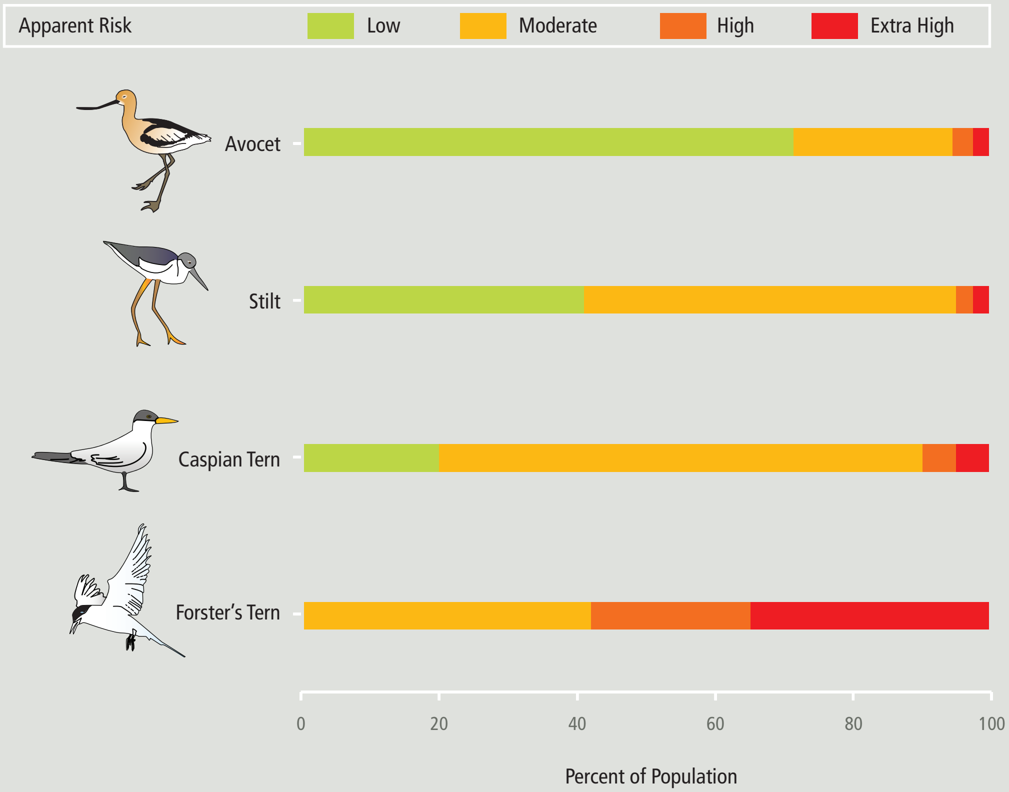

Footnote: Inset shows bars on a common scale for direct comparison.

Contacts: U.C. Davis Study – Darell Slotton, dgslotton@ucdavis.edu.
RMP Study – Ben Greenfield, ben@sfei.org

**Small fish mercury monitoring is revealing the spatially and temporally dynamic nature of methylmercury concentrations in the Estuary.** Small fish are an excellent indicator of fine-scale spatial and temporal patterns in mercury and wildlife exposure to mercury in aquatic ecosystems. Two studies in 2006 combined to provide thorough coverage of the Estuary. In the larger of the two studies, Darell Slotton and colleagues at U.C. Davis have sampled large numbers of small fish of several species throughout the north Bay, Delta, and Central Valley in an effort to evaluate the local and regional impacts of habitat restoration on mercury in the food web. The most widespread species they sampled is the Mississippi silverside (*Menidia audens*), which has proven to be a particularly effective mercury indicator for the Estuary. The fish sampled are only a few months old and are good indicators of recent concentrations of methylmercury in the food web.

One highlight of the extensive silverside sampling by U.C. Davis in 2006 (blue bars) was the low mercury concentrations observed in the Napa Marsh complex. The former salt ponds of the Napa Marsh are the site of some of the most extensive wetland restoration activities in the Bay-Delta watershed. Mercury concentrations observed in this region in 2005 were low, and concentrations in 2006 were even lower. Silversides collected within the recently breached Pond 4/5 complex not only contained dramatically lower mercury than all other samples in the local region, they had the lowest mercury ever recorded for this species across the entire watershed, averaging 14 ppb. These data indicate that some wetlands, even during restoration, can be methylmercury sinks, contrary to the common expectation that they would be methylmercury sources. Other surprises from the 2006 sampling by U.C. Davis were high concentrations along the Petaluma River, an area not previously known for methylmercury contamination, and high concentrations in Suisun Marsh, an area that had much lower concentrations in 2005. Most notable were previously unknown seasonal spikes in small fish mercury, to levels significantly above the fall concentrations shown in the Figure (to as high as 1000 ppb). These were all associated with various forms of seasonal or episodic flooding of dry soils.

The RMP also performed a complementary smaller study of mercury in Mississippi silverside and other small fish species in the Estuary in 2006 (pink bars). Concentrations in the South Bay were high compared to the rest of the Estuary, but a bit lower than observed in South Bay in 2005. The highest concentration at RMP sites in 2006 was measured at a Central Bay location that was not sampled in 2005.




Footnote: Risk categories are based on blood concentrations and derived from the sensitivity of common loons.

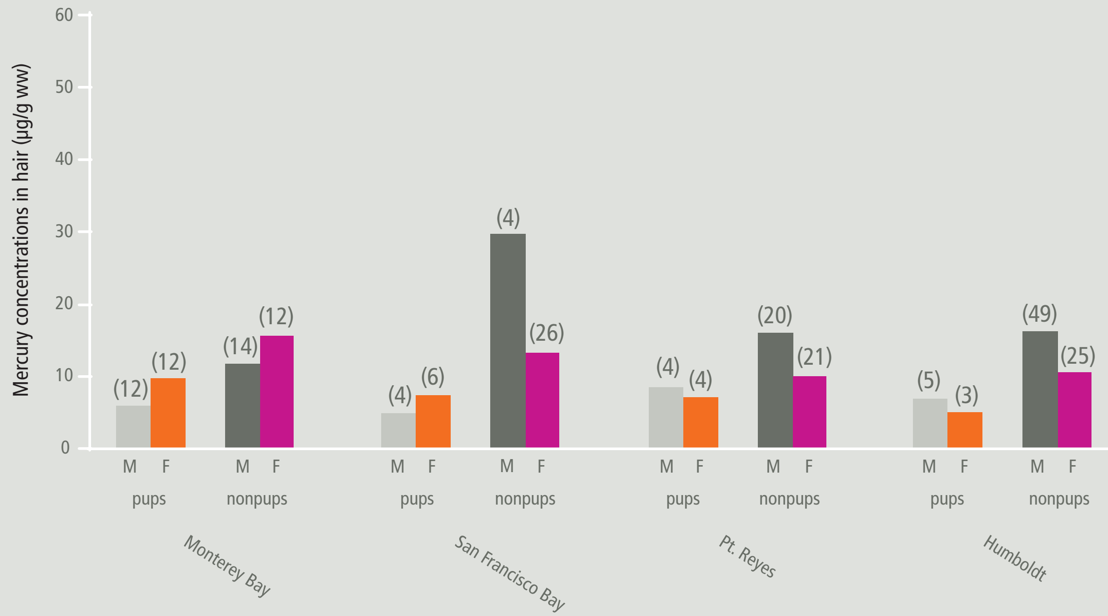
From: Ackerman et al. 2007. Mercury in birds of the San Francisco Bay-Delta: trophic pathways, bioaccumulation, and ecotoxicological risk to avian reproduction. 2006 Annual Administrative Report. http://www.delta.dfg.ca.gov/erp/docs/wq_mercuryissues/Mercury%20in%20Birds%20of%20the%20SF%20Bay%20Delta_Apr07.pdf

Contacts: Collin Eagles-Smith, U.S. Geological Survey, ceagles-smith@usgs.gov. Josh Ackerman, U.S. Geological Survey, jackerman@usgs.gov

**Methylmercury may pose substantial risks to breeding birds in San Francisco Bay.** Widespread mercury contamination of San Francisco Bay has resulted in potentially harmful concentrations of methylmercury in fish and wildlife, yet it remains unclear what ecological effects are actually occurring. To better understand the impact that mercury contamination may be having on local wildlife populations, scientists from the U.S. Fish and Wildlife Service and U.S. Geological Survey have examined four species of waterbirds that commonly breed within the Estuary: American avocets, black-necked stilts, Caspian terns, and Forster's terns. Mercury concentrations in bird blood and eggs were compared to available thresholds. Blood mercury concentrations were lowest in avocets and stilts, which feed mainly on invertebrates, and highest in Caspian terns and Forster's terns, which feed on fish. The study found that 6% of avocets, 5% of stilts, 10% of Caspian terns, and 57% of Forster's terns were at high to extra-high risk of reproductive impairment due to their blood mercury levels (>3.0 parts per million or ppm). A similar pattern was found for egg mercury concentrations, where 0% of avocet, 10% of stilt, and 46% of Forster's tern eggs had mercury concentrations (>1.8 ppm) placing them at high to extra high risk of potentially reduced hatching success and subsequent chick survival.

These results indicate that wetland-dependent wildlife, particularly fish-eating birds, may be at substantial risk from mercury contamination within the Bay. However, the findings should be interpreted with caution. Due to the general lack of data on the sensitivity of birds to mercury contamination, especially in San Francisco Bay, the interpretation is based on risk thresholds developed for loons (blood and eggs) and mallards (eggs) from other areas in North America. It is currently unknown whether these species are appropriate surrogates for the Bay shorebird and tern species that were studied. Indeed, there may be substantial variability in the susceptibility of different species to methylmercury toxicity. Better information on waterbird sensitivities to methylmercury exposure is needed to better characterize the risk to Estuary birds.

Tern eggs. Photograph by Joel Shinn.



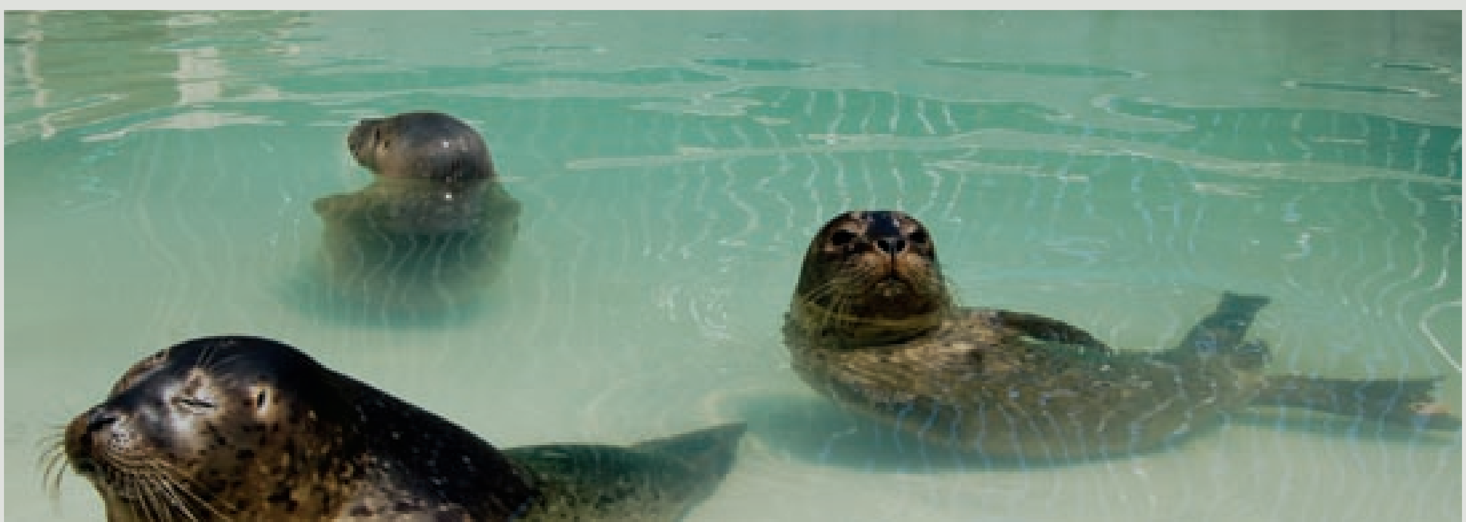

Footnote: Total mercury (THg) concentrations (ppm wet weight; mean) in hair of harbor seals in central (Monterey Bay, San Francisco Bay, and Pt. Reyes) and northern California (Humboldt), USA, from 2003 to 2005 for different age classes, sexes (males=M and females=F), and locations. Age classes were defined as pups and non-pups because only one juvenile male was sampled in San Francisco Bay. Sample sizes are noted in parentheses.

From: Brookens, T.J., J.T. Harvey, and T.M. O'Hara. 2007. Trace element concentrations in the Pacific harbor seal (*Phoca vitulina richardii*) in central and northern California. Science of the Total Environment 372: 676–692.

Contact: Tiffini Brookens, Moss Landing Marine Laboratories, tjbrooken@aol.com

**Harbor seals are useful indicators of contamination of the Estuary by mercury, PCBs, and other pollutants that reach high concentrations at the top of the food web.** Last year's Pulse (page 19) described how mercury can be easily measured in a strand of hair, and presented data from a national survey of mercury in human hair. As in humans, measurement of mercury in seal hair provides an informative and non-invasive means of obtaining data on exposure to this pollutant in the Bay food web.

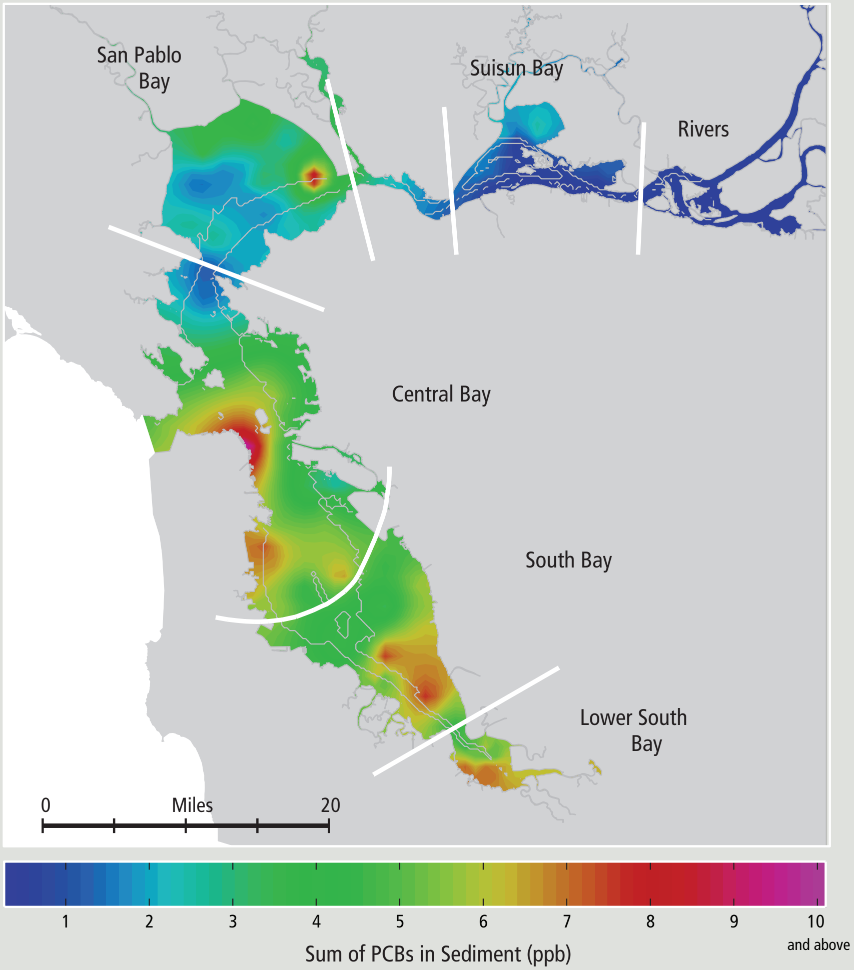
Researchers from Moss Landing Marine Laboratories recently completed a study in which mercury was measured in the hair of harbor seals *(Phoca vitulina)* from throughout central and northern California. The average concentration of mercury in hair of all of these seals was 15 ppm. Concentrations in seal hair are much higher than the human hair values presented in the last Pulse, which peaked at around 1 ppm. The high concentrations in seal hair are consistent with their dietary dependence on Bay fish. An interesting finding from this study was the lack of statistically significant variation in concentrations among the four locations examined – San Francisco Bay, Monterey Bay, Point Reyes, and Humboldt Bay – even though San Francisco Bay generally is more contaminated with mercury than the other locations. This was partially due to the small number of samples that could be obtained, especially for adult males in San Francisco Bay. Movement of seals among the four locations may have also influenced the results. The study also found that adults had higher concentrations than young seals, and the adult males were higher than adult females.



Harbor seals at Marine Mammal Center. Sausalito, CA. Photograph by Susan Klosterhaus.

# PCBs

PCB contamination remains one of the greatest water quality concerns in the Estuary, and PCB clean-up 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.

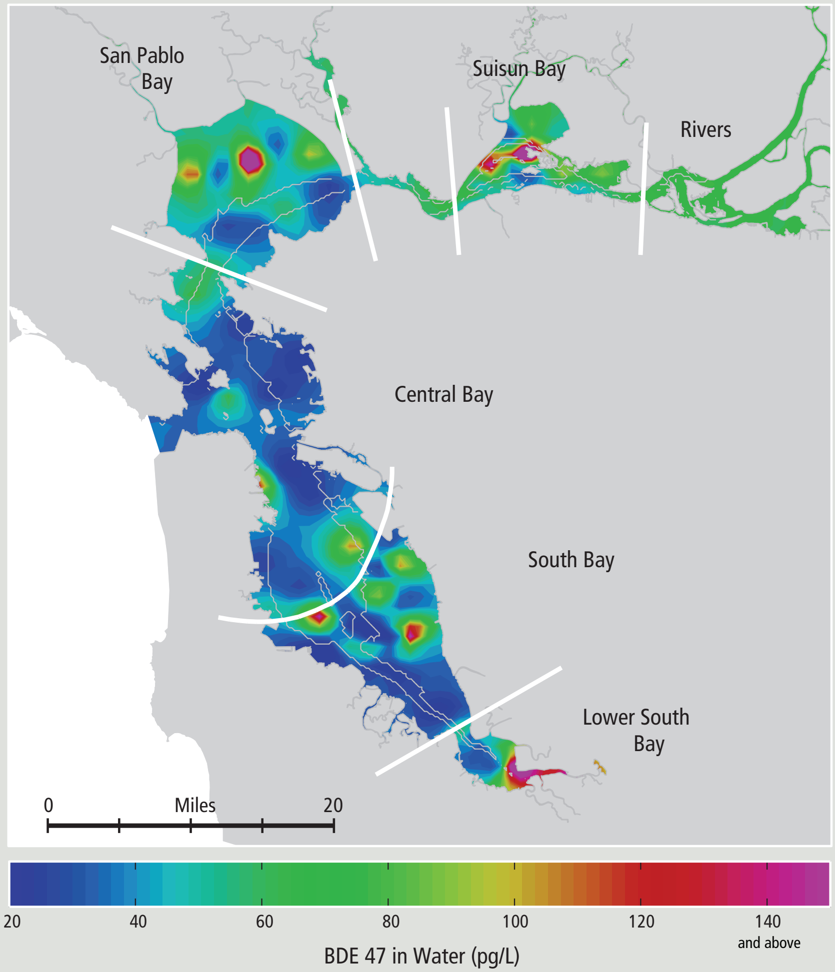



Footnote: Plot based on 141 RMP data points from 2004 – 2006. Data from 2002 and 2003 are not available. The maximum concentration was 25 ppb near Mare Island in 2004.

**PCB concentrations in Bay sediment measured from 2004 – 2006 were highest in the southern reach of the Estuary (Lower South Bay, South Bay, and the southern part of Central Bay).** Models suggest that sediment PCB concentrations must decline to about 1 ppb in order to bring concentrations in sport fish below thresholds of concern for human health. Average concentrations were 5.7 ppb in Central Bay, 5.4 ppb in Lower South Bay, 5.4 ppb in South Bay, 3.6 ppb in San Pablo Bay, and 1.4 ppb in Suisun Bay. The Suisun Bay average for 2006 was 0.8 ppb.

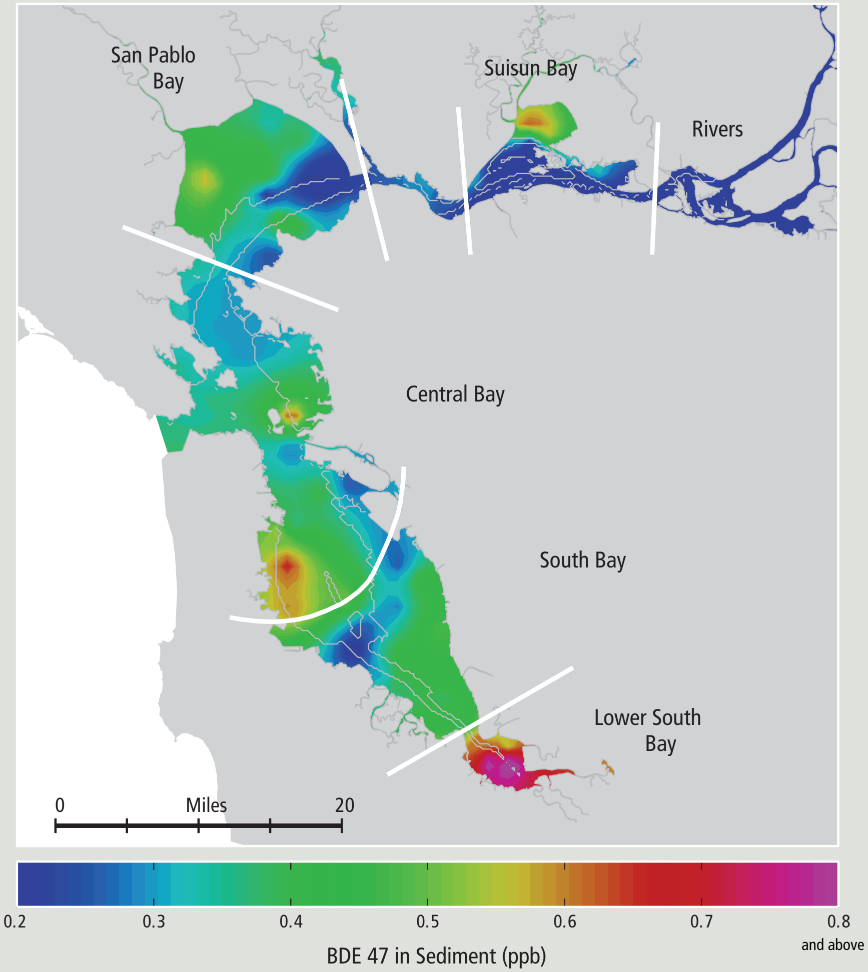
# PBDEs

PBDEs, a class of bromine-containing flame retardants that was practically unheard of in the early 1990s, increased rapidly through the 1990s and are now a pollutant of concern in the Estuary. 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 exist yet 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. Plot based on 150 RMP data points from 2002 – 2006. The maximum concentration was 337 pg/L observed in Suisun Bay in 2004. Data are for total BDE 47 in water.

**The highest concentrations of PBDEs in water from 2002 – 2006 were scattered throughout the Bay.** The highest concentrations of BDE 47 (one of the most abundant PBDEs and an index of PBDEs as a whole), greater than 300 pg/L, were observed in Suisun Bay and San Pablo Bay. Suisun Bay had the highest average concentrations over the five-year period (84 pg/L), suggesting the presence of PBDE inputs into the northern Estuary. Concentrations across most of the Bay were less than 50 pg/L.

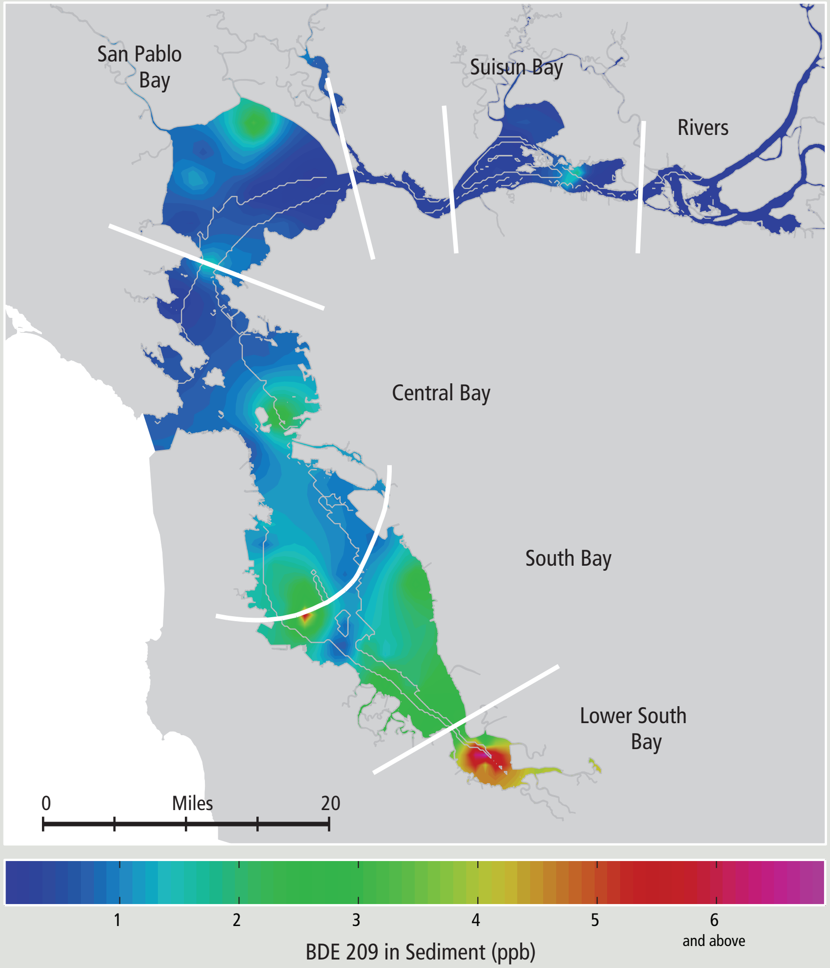



Footnote: BDE 47 is one of the most abundant PBDEs and was consistently quantified by the lab. Plot based on 140 RMP data points from 2004 – 2006. Data from 2002 are available but were inconsistent with data for the other three years. The maximum concentration was 3.8 ppb in Lower South Bay in 2005.

**Average concentrations of BDE 47 in sediment from 2004 – 2006 were highest in Lower South Bay (0.83 ppb).** Average concentrations in the other segments were all below 0.44 ppb. Suisun Bay had the lowest average (0.33 ppb), but northern Suisun Bay had some relatively high concentrations. Concentrations within each segment and in the Bay as a whole did not suggest a trend over the three-year period.

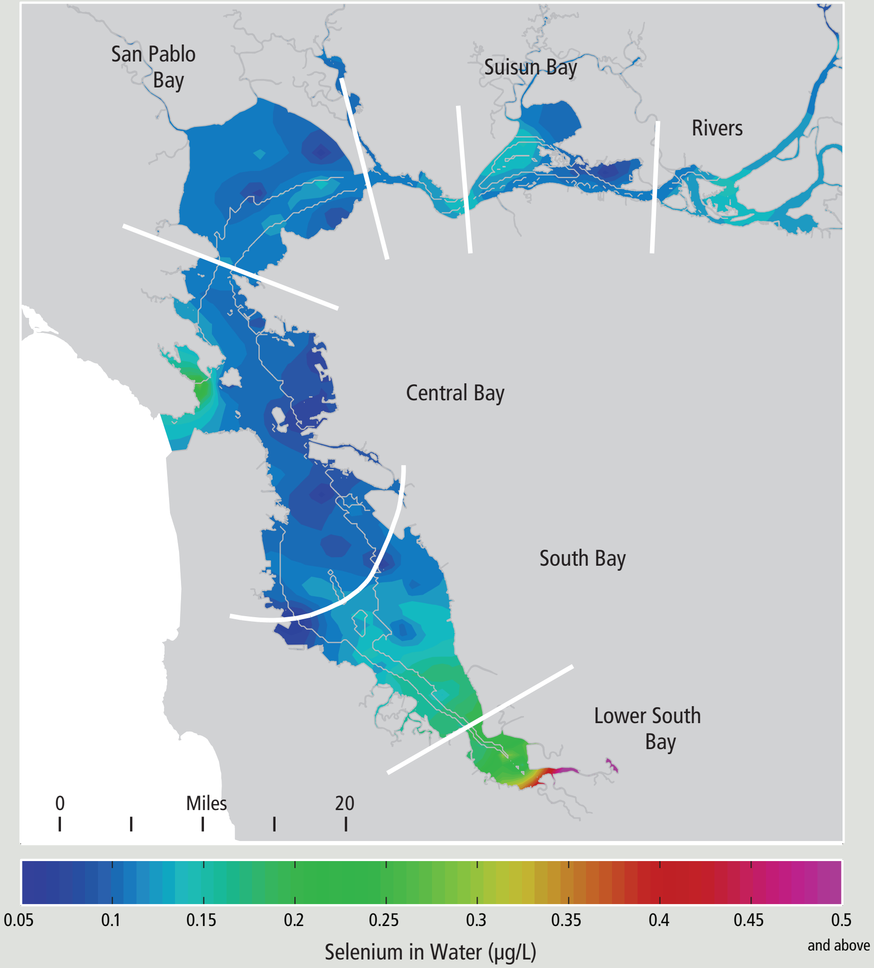
# Selenium

Selenium contamination is a continuing concern in the Estuary. Selenium accumulates in diving ducks in the Bay to concentrations that pose a potential health risk to human consumers. Selenium concentrations also pose a threat to wildlife in the Estuary. 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: BDE 209 shown as an index of the "deca" PBDE mixture. Plot based on 90 RMP data points from 2004 and 2006. The maximum concentration was 19 ppb in South Bay in 2006.

**Concentrations of BDE 209 in 2006 were higher than in 2004. 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.** Data from only two years are available because BDE 209 is challenging to measure. As for BDE 47, average concentrations of BDE 209 in 2004 and 2006 were highest in Lower South Bay (9.0 ppb in 2006). Average concentrations in the other segments in 2006 ranged from 4.9 in South Bay to 0.6 in Suisun Bay. Average concentrations in Lower South Bay, South Bay, Central Bay, and for San Francisco Bay as a whole were all two times higher in 2006 than in 2004. Data from additional years will be needed to determine whether this represents an increasing trend or simply year-to-year variability.



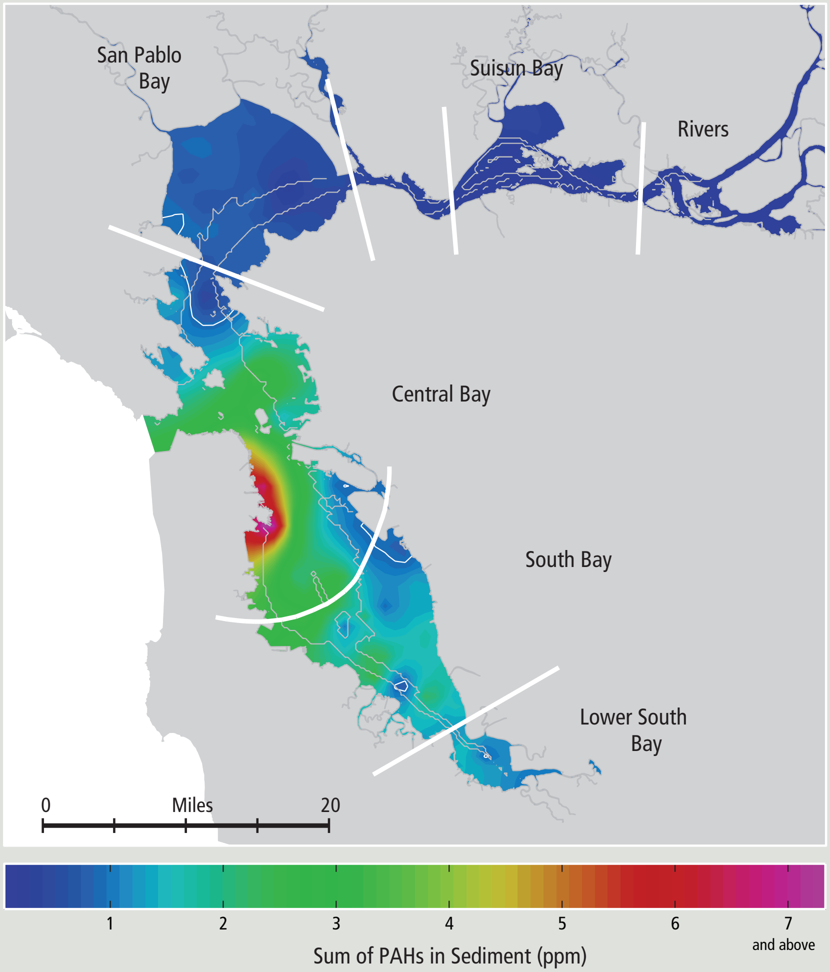

Footnote: Plot based on 146 RMP data points from 2002 – 2006. The maximum concentration was 1.2 µg/L in the Southern Sloughs in 2002. Data are for total selenium.

**Selenium concentrations in water are well below the water quality objective established by the California Toxics Rule, yet concerns still exist for human and wildlife exposure at current levels of contamination.** The highest concentration observed in water from 2002 to 2006 was 1.15 µg/L, much lower than the CTR objective (5 µg/L). The Lower South Bay had a higher average concentration (0.25 µg/L) than the other Bay segments (all other averages were between 0.12 and 0.16 µg/L).

# PAHs

PAHs (polycyclic aromatic hydrocarbons) are included on the 303(d) List for several Bay locations. There is also concern that PAH concentrations in sediment across much of the Bay exceed a threshold for potential impacts on early life stages of fish. Increasing population and motor vehicle use in the Bay Area are cause for concern that PAH concentrations could increase over the next 20 years. On the other hand, PAH concentrations in Bay Area air have declined over the past ten years, and if PAH inputs to the Bay can be decreased, concentrations are expected to drop quickly.



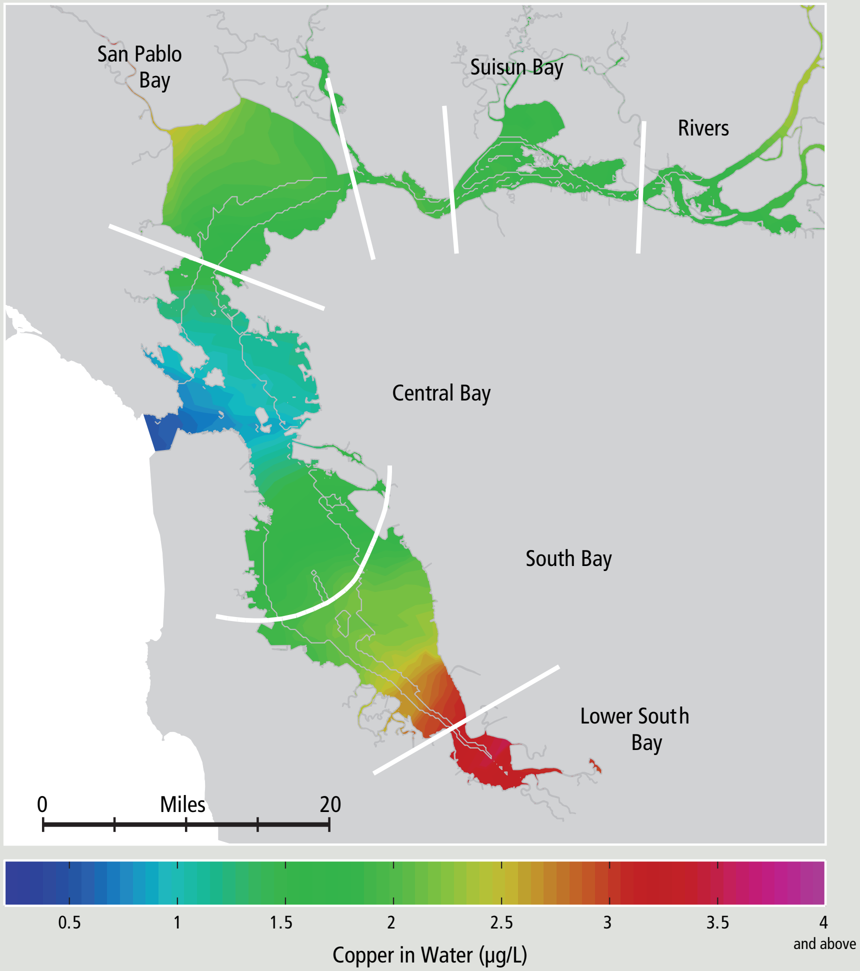



Footnote: Plot based on 236 RMP data points from 2002 – 2006. 1 ppm threshold is based on Johnson, L.L., Collier, T.K., Stein, J.E. 2002. An analysis in support of sediment quality thresholds for polycyclic aromatic hydrocarbons (PAHs) to protect estuarine fish. Aquatic Conservation: Marine and Freshwater Ecosystems 12, 517-538. The maximum concentration was 12 ppm in Central Bay in 2005.

**PAH concentrations in sediment across much of the Estuary exceed a threshold for potential health risks to estuarine fish.** Dredging regulators have been applying a 1 ppm threshold from Johnson et al. (2002) in evaluating PAH risks from dredging projects. Johnson et al. (2002) concluded that above 1 ppm there appears to be a substantial increase in the risk of contaminant-related injury to English Sole, a thoroughly-studied species not common in the Bay but considered representative of estuarine flatfish. Central Bay had the highest average concentration (3.4 ppm) of any Bay segment over the last five years. South Bay had the next highest average concentration (1.9 ppm), followed by Lower South Bay (1.4 ppm), San Pablo Bay (0.8 ppm), and Suisun Bay (0.3 ppm).

# Copper

Copper was a major concern in the Estuary in the 1990s, as concentrations were frequently above the water quality objective. An evaluation of the issue by the Water Board and stakeholders led to new water quality objectives for copper and nickel in the Lower South Bay (less stringent but still considered fully protective of the aquatic environment), pollution prevention and monitoring activities, and the removal of copper from the 303(d) List.



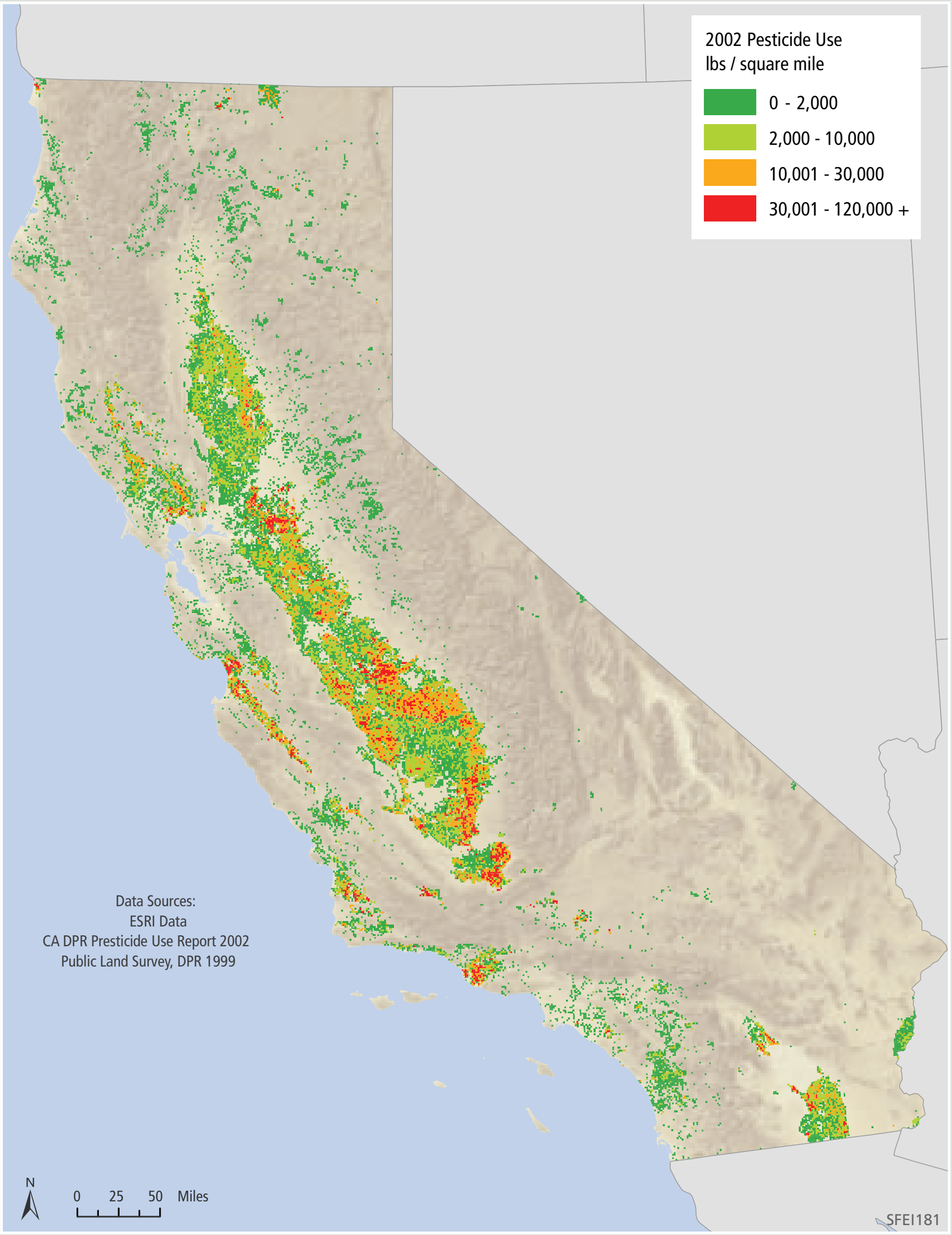

Footnote: Plot based on 159 RMP data points from 2002 – 2006. Data are for dissolved copper.

**In the past five years, none of the 159 water samples analyzed had a dissolved copper concentration above site-specific objectives for the Bay.** The Water Board is in the process of adopting site-specific objectives of 6.9 µg/L for the South Bay and 6.0 µg/L for Central Bay, San Pablo Bay, and Suisun Bay. A site-specific objective of 6.9 µg/L already is in place for Lower South Bay. The highest concentration observed was 4.3 µg/L. The Lower South Bay had the highest average concentration (3.4 µg/L), followed by South Bay (2.2 µg/L), San Pablo Bay (2.0 µg/L), Suisun Bay (1.8 µg/L), and Central Bay (1.3 µg/L).

# Current Use Pesticides

Current use pesticides include chemicals such as pyrethroid and organophosphate insecticides used to control insects in agriculture and urban and suburban environments. In recent years, a shift in usage away from organophosphates and toward pyrethroids has occurred. Agricultural use of organophosphate insecticides has been reduced to about half the levels of the mid-1990s, and urban use has been almost entirely eliminated. Pyrethroid insecticide use in agriculture, structural pest control, and household applications has increased as the use of organophosphate pesticides has declined. Fish and aquatic invertebrates are quite sensitive to pyrethroids, raising concern for possible non-target impacts on aquatic environments.






Footnote: Data from the Pesticide Use Reporting Program (www.cdpr.ca.gov/docs/pur/purmain.htm), compiled by the Pesticide Action Network (www.panna.org).

Contact: Susan Kegley, Pesticide Action Network, skegley@panna.org

**The Bay watershed supports intensive agricultural activity that is associated with the use of millions of pounds per year of pesticides.** California's Department of Pesticide Regulation administers a Pesticide Use Reporting (PUR) Program that is recognized as the most comprehensive in the world. Under the Program, all agricultural pesticide use must be reported on a monthly basis. The database includes pesticide applications to farms, parks, golf courses, cemeteries, rangeland, pastures, and along roadside and railroad rights-of-way, as well as treatments in poultry, fish, and some livestock applications. Significant uses not included in the program are home and garden use and most industrial and institutional uses.

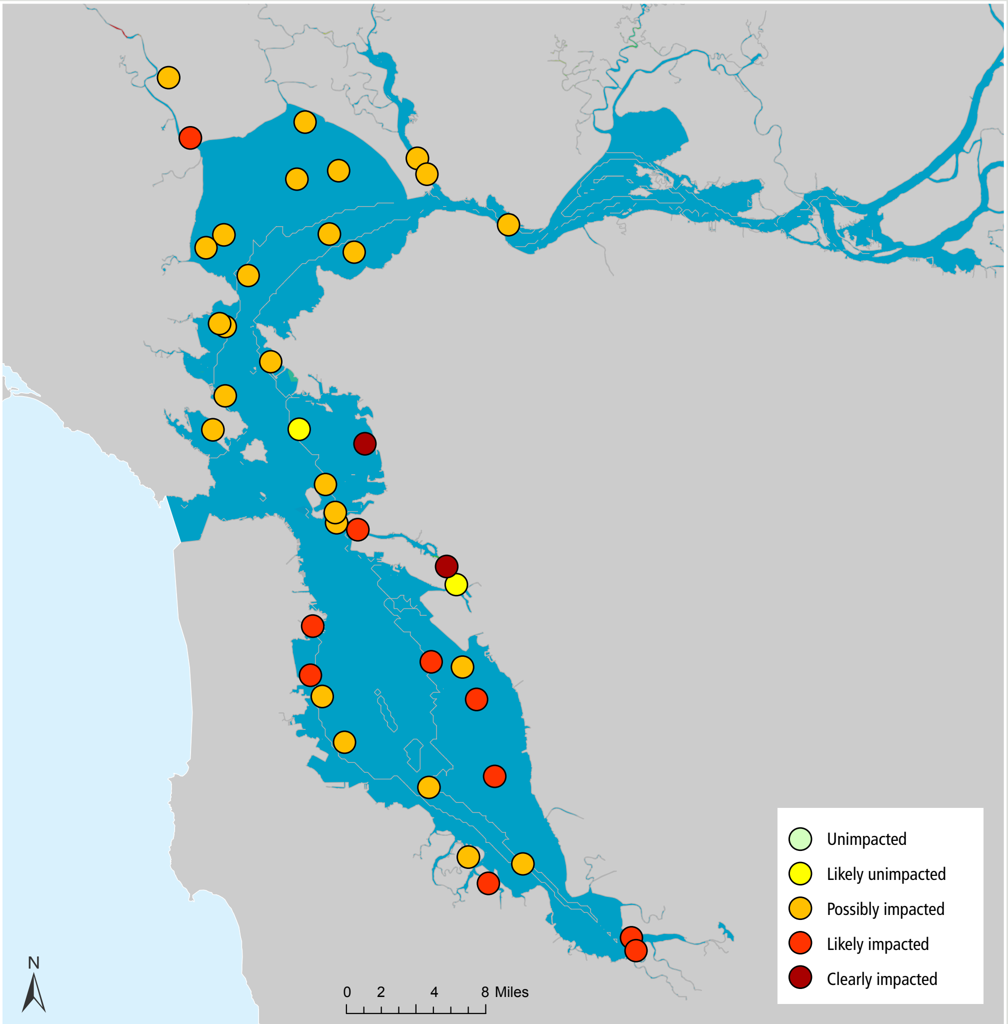
The Pesticide Action Network has developed a website (The Water & Pesticides Information Center – WaterPIC – http://www.pesticideinfo.org/waterpic/step1.jsp) that provides information on reported agricultural pesticide use in California from the PUR Program and measured surface water concentrations in the environment from other programs. The site allows retrieval of graphs and tabulations of the data.

The map shown is based on data compiled by the Pesticide Action Network for 2002. On a statewide basis the Central Valley and North Bay watersheds stand out as having relatively heavy agricultural use of pesticides. The reliance on chemicals for pest control in agriculture and urban applications in the watershed means that the RMP must remain vigilant for pesticides that could have unintended effects on aquatic organisms in the Estuary.

## Pesticides and POTWs

Bay Area POTWs, through the statewide organization Tri-TAC (a Technical Advisory Committee on state and federal regulatory issues affecting POTWs), have taken an active role in addressing non-agricultural use of pesticides and their potential pathways to POTWs and receiving waters. Tri-TAC has written numerous letters to EPA and the California Department of Pesticide Regulation, available on the web at http://www.tritac.org/letters.htm.

# Sediment Quality Triad




Footnote: SCCWRP. 2007. Draft Technical Report: Preliminary Statewide Sediment Assessments for Bays using the Proposed SQO Methodology. Southern California Coastal Water Research Project, Costa Mesa, CA.

Contacts: Bruce Thompson (bruce@sfei.org) and Sarah Lowe (sarahl@sfei.org), San Francisco Estuary Institute. Steve Bay, Southern California Coastal Water Research Project, steveb@sccwrp.org

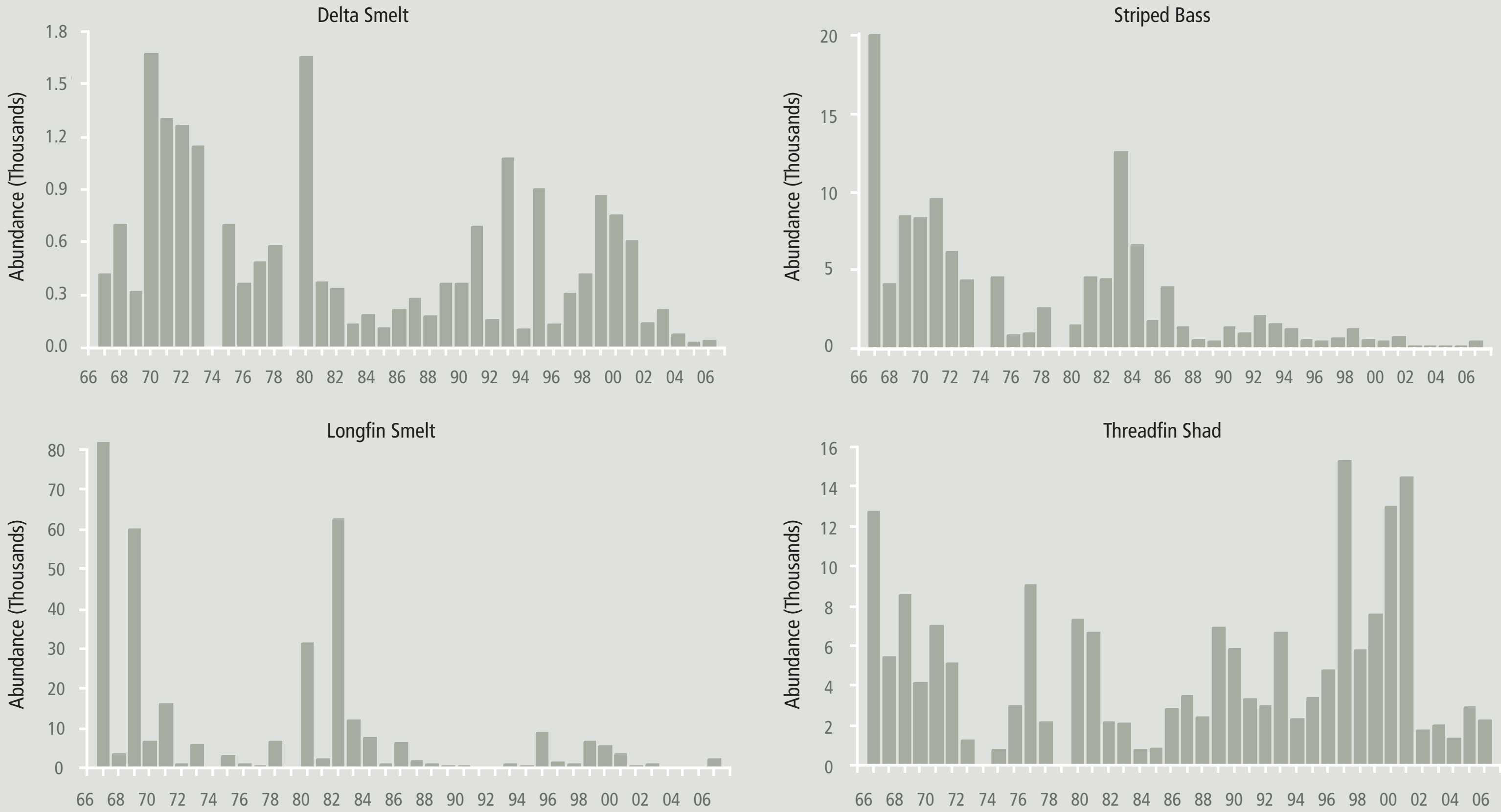
**Monitoring data indicate that adverse impacts on sediment quality are possible throughout most of San Francisco Bay.** The State Water Resources Control Board (State Water Board) is currently developing sediment quality objectives (SQOs) for California bays and estuaries. The new SQOs will be the first ever established for California water bodies, intended for use in assessing whether beneficial uses are protected, at risk, or degraded. The proposed SQOs for assessing impacts on aquatic life are based on a novel approach that employs three lines of evidence including chemical concentrations, toxicity, and benthic community composition (the diversity and abundance of sediment-dwelling organisms). The combination of these three indicators of sediment quality is known as the "sediment quality triad".

A procedure for combining data from these three lines of evidence has been developed and was tested this year in a statewide assessment of sediment quality data. Forty sites from the Bay were sampled for the sediment quality triad in 2000 in a joint effort by the National Oceanic and Atmospheric Administration and the US Environmental Protection Agency, and these data were used for the assessment.

Based on the results from each leg of the triad, each Bay sampling location was assigned to one of five categories of degree of impact. No locations fell into the "unimpacted" category, and only two locations (representing 4% of the total area of the Bay) were "likely unimpacted". Some degree of impact was considered possible in the remaining 96% of the Bay. Most of the Bay (73%) was classified as "possibly impacted". Impacts were considered "likely" in 19% of the Bay and "clearly" in 4% of the Bay.

A primary driver of the results for San Francisco Bay was sediment toxicity, which has been documented by the RMP as a persistent and widespread problem (page 53). Future work on this issue in the RMP will be focused on 1) continuing, expanding, and refining this analysis to include evaluation of all regions of the Bay and more of the available sediment quality information and 2) identification of the causes of sediment toxicity and alterations in benthic community structure.

# Fisheries Pelagic Organism Decline

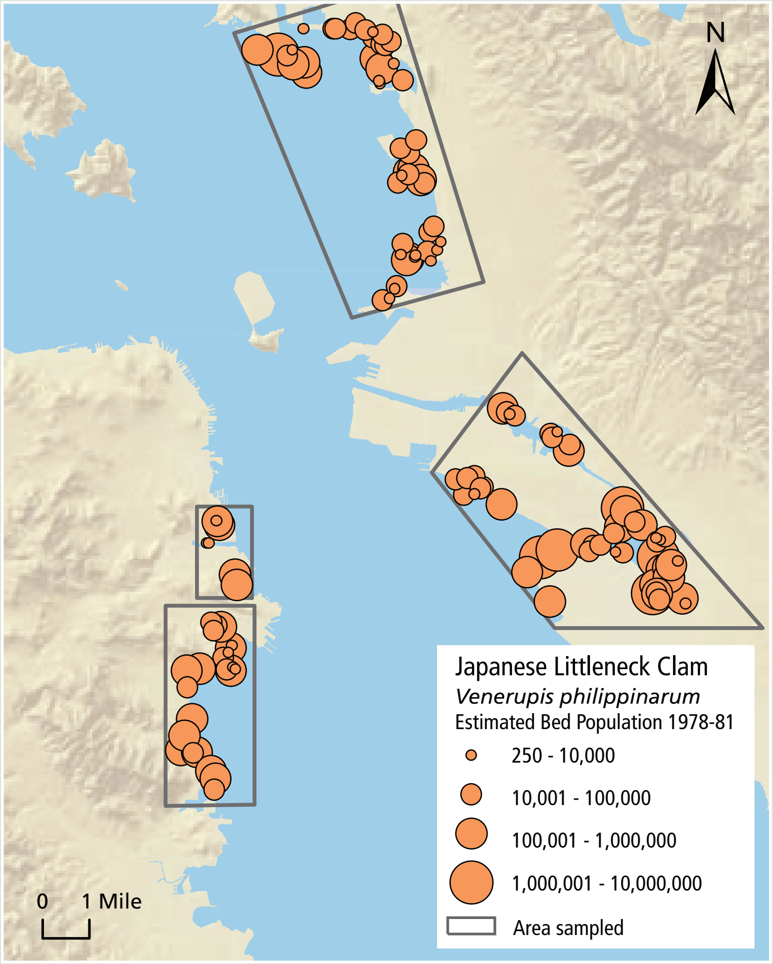


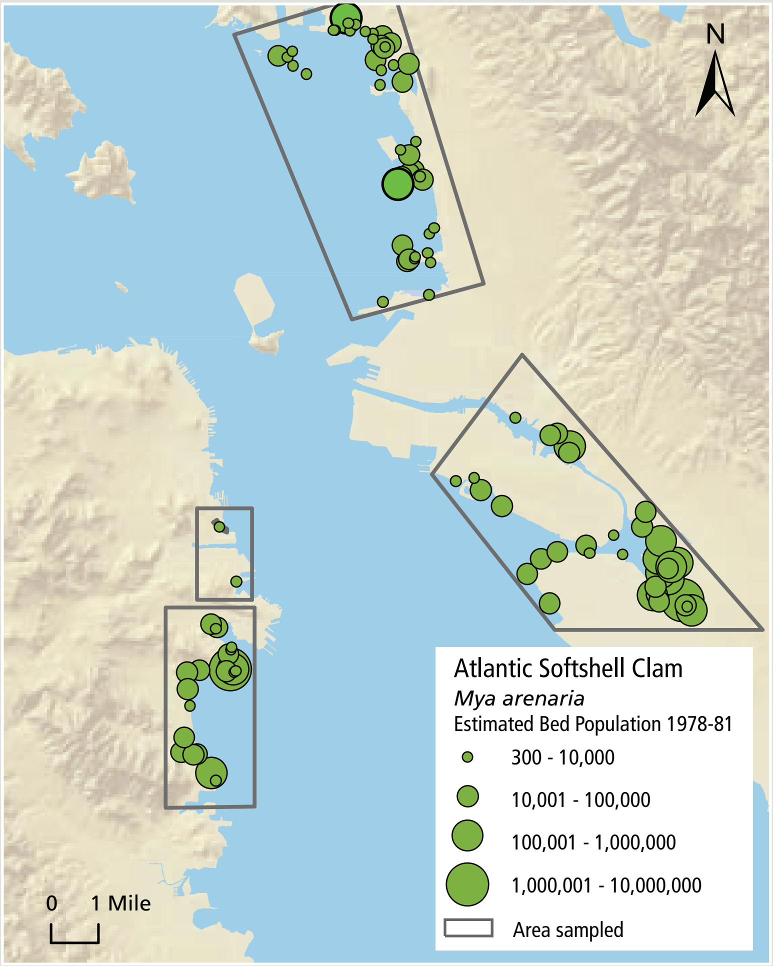

Footnote: Data from the Fall Midwater Trawl. Additional information available at: http://science.calwater.ca.gov/pod/pod_index.shtml

Contact: Randy Baxter, California Department of Fish and Game, rbaxter@dfg.ca.gov

**Several important fish species in the Estuary are showing serious declines.** Summer and fall abundance indices calculated by the Interagency Ecological Program (IEP) suggest recent marked declines in numerous pelagic fishes in the upper San Francisco Estuary (the Delta and Suisun Bay), known as the "pelagic organism decline (POD)". The fall indices have been collected for all but two of the last 30 years. The indices for the last few years include record lows for Delta smelt (listed as threatened under the Endangered Species Act) and striped bass and near-record lows for longfin smelt and threadfin shad. In 2007, surveys of 20 millimeter Delta smelt (data not shown) came in at such low numbers that the state and federal pumping operations that supply drinking water to millions of Californians and a principal source of irrigation water for California farmers were drastically curtailed. The State Water Project pumps were completely shut down for nine days in late May and early June. The crisis surrounding Delta smelt is precipitating a major reevaluation of water management in the Delta.

In response to these changes, the IEP is making a concerted effort to evaluate the potential causes. Some of the primary factors that are suspected to be acting individually or in concert to affect these species include toxic chemicals such as pyrethroid insecticides or toxins produced by newly abundant blue-green algae, invasive species that may be reducing the food supply for fish, and water project operations that may be removing a larger proportion of these populations in recent years.




Contact: Andrew Cohen, San Francisco Estuary Institute, acohen@sfei.org

**Little is known about the distribution of shellfish beds in the Bay.** Although there are no longer any commercial shellfish beds in the Bay, individuals sometimes collect clams, mussels, or oysters for their own consumption. We know little about the current distribution of these shellfish beds. SFEI is assembling a geographic database incorporating data from historic sources and from ongoing and planned surveys, which will allow us to assess changes in bed conditions, risks, and management options, etc. These two maps are an example of the output from the database, showing the location and size of beds of two species of edible clam, the Manila or Japanese Littleneck Clam (*Venerupis philippinarum*) and the Atlantic Softshell Clam (*Mya arenaria*), based on surveys conducted by James Sutton for the City and County of San Francisco and the East Bay Municipal Utility District.

# Water Quality Monitoring



SWAMP
Surface Water Ambient Monitoring Program

### The Surface Water Ambient Monitoring Program (SWAMP)

SWAMP is a program of the State Water Resources Control Board designed to assess the condition of surface waters throughout California. There are statewide and regional components to SWAMP. The regional Bay Area SWAMP component monitors water quality in Bay Area watersheds; contaminants in fish from reservoirs, the ocean, and bays other than San Francisco Bay; and trash in the watersheds. The major goal of the Bay Area SWAMP is to develop a watershed monitoring coalition with stormwater programs and others to ensure collaborative, consistent, and high-quality watershed monitoring.

**The Surface Water Ambient Monitoring Program (SWAMP) has been conducting water quality monitoring in watersheds throughout the Bay Area.** Two reports have recently been released on the first three years of monitoring from 2001 – 2004. The first report assesses water quality in nine watersheds: Walker Creek, Lagunitas Creek, San Leandro Creek, Wildcat/San Pablo Creek, Suisun Creek, Arroyo Las Positas in 2001-2002; and Pescadero/Butano Creek, San Gregorio Creek, and Stevens/Permanente Creek in 2002-2003. The second report assesses another four watersheds (Kirker Creek, Mt. Diablo Creek, Petaluma River, and San Mateo Creek) in 2003-2004. Sampling sites in these surveys were selected with the goal of identifying general sources of water quality stressors (Figure 1).

Bioassessment data (describing the community composition of organisms that live in the sediment) indicated a relationship between biological integrity in streams and land use practices (Figure 2). Stream sites receiving runoff from open space and rural residential areas had the healthiest communities and sites draining urban areas had the most degraded communities. Physical habitat conditions, particularly riparian habitat and channel alteration, were associated with the health of benthic (sediment-dwelling) communities. One of the most important natural factors affecting benthic communities was flow intermittency. Pescadero/Butano and San Gregorio Creeks had the highest water quality and most undisturbed benthic communities of the watersheds surveyed.

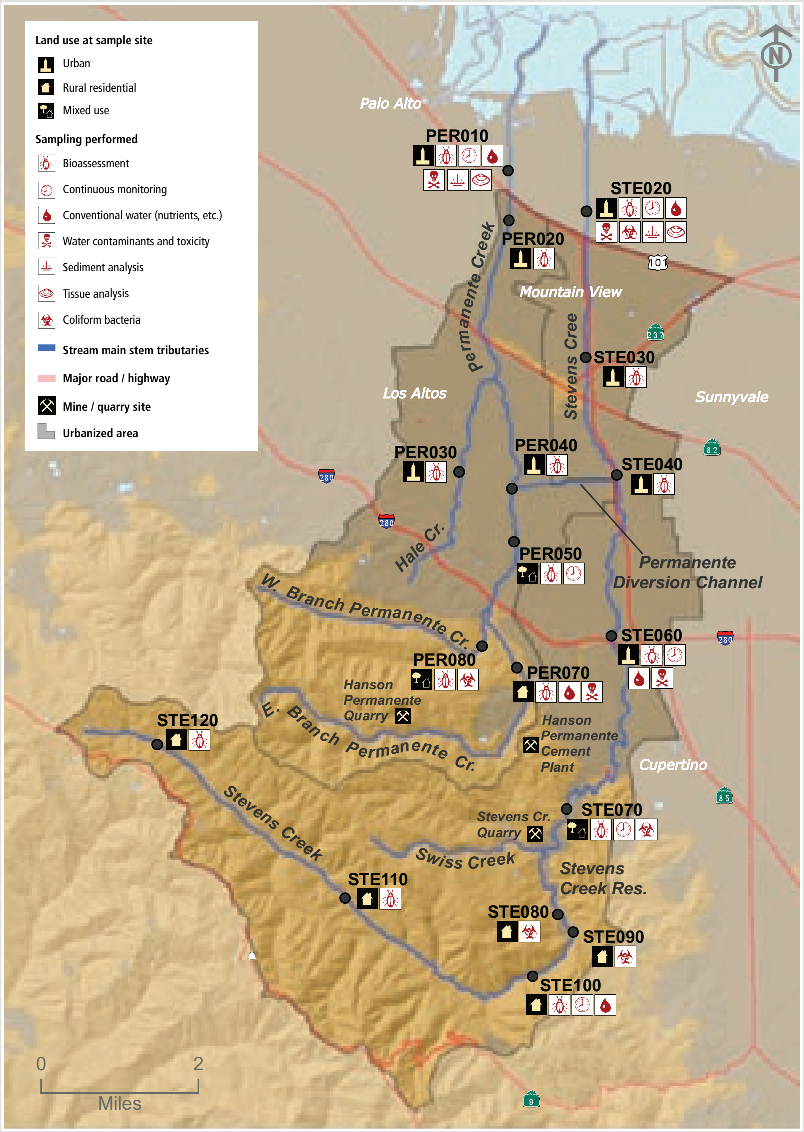
Elevated temperatures and depressed dissolved oxygen concentrations were common throughout the watersheds, and these conditions were often beyond ranges supportive of salmonid species. Across the Bay Area, lower temperatures and higher dissolved oxygen were observed to be associated with the presence of intact riparian habitat. Arroyo Las Positas and Kirker Creek had the highest number of temperature and dissolved oxygen measurements outside ranges acceptable for salmonids or cold water habitat.

Nutrients were often elevated in urban areas. The mean nitrate level for urban streams was more than twice that for streams draining agricultural areas and nearly ten times that of streams in open space areas. Most measured nitrate values exceeded the EPA reference guideline for aquatic life. Arroyo Las Positas and San Leandro Creek had the highest nitrate concentrations.

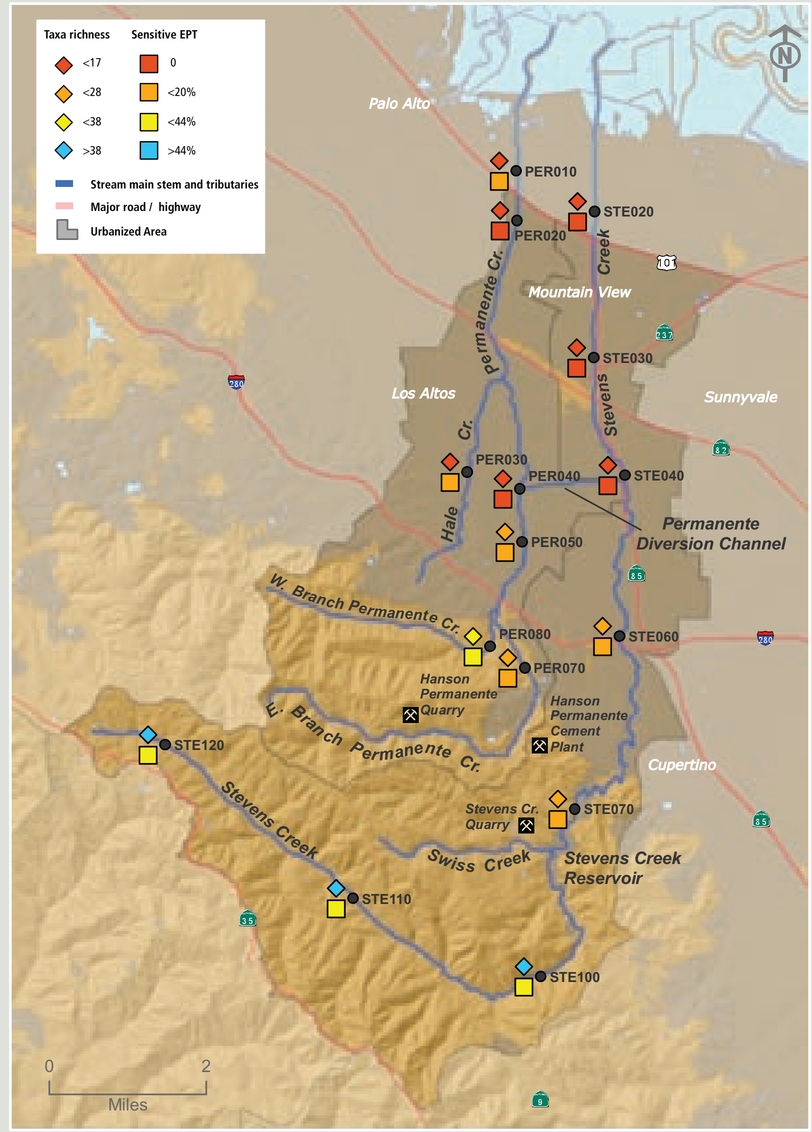
In general, concentrations of contaminants were below regulatory thresholds. However, urban areas tended to have the highest concentrations. This was particularly true of PAHs.

Throughout the region, toxicity was moderate. Stevens Creek and Kirker Creek had the highest aquatic toxicity. San Leandro, Kirker and San Mateo creeks had the highest sediment toxicity. Relationships between toxicity and individual chemicals were not clear. The observed toxicity was most likely due to the combined action of a variety of contaminants. Pyrethroids may have played a role in causing sediment toxicity, but were not measured until 2005.

## Figure 1
## Study Design




## Figure 2
## Bioassessment Results




Footnote: From SFBRWQCB. 2007. Water quality monitoring and bioassessment in nine San Francisco Bay Region watersheds: Walker Creek, Lagunitas Creek, San Leandro Creek, Wildcat Creek/San Pablo Creek, Suisun Creek, Arroyo Las Positas, Pescadero Creek/Butano Creek, San Gregorio Creek, and Stevens Creek/Permanente Creek. Oakland, CA: Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board. http://www.waterboards.ca.gov/sanfranciscobay/monitoring/RB2SWAMPYr%201-2Rpt06152007.pdf

SFBRWQCB 2007. Water Quality Monitoring and Bioassessment in Four San Francisco Bay Region Watersheds in 2003-2004: Kirker Creek, Mt. Diablo Creek, Petaluma River, and San Mateo Creek. Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board, Oakland, CA. http://www.waterboards.ca.gov/sanfranciscobay/monitoring/RB2SWAMPYr3Rpt061507.pdf

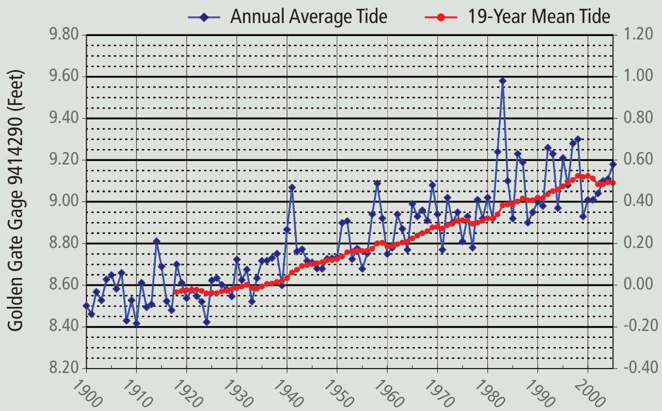
Contact: Karen Taberski, San Francisco Bay Regional Water Quality Control Board, KTaberski@waterboards.ca.gov

# Sea Level Rise



## Figure 1

Golden Gate Annual Average and 19-Year Mean Tide Levels




Records show a 7 inch rise in sea level since 1920

Footnote: Graph from URS. 2007. Status and Trends of Delta-Suisun Services, Public Review Draft. Prepared by URS Corporation for the California Department of Water Resources. http://deltavision.ca.gov/DeltaVisionStatusTrends.shtml

## Figure 2

San Francisco Bay Scenarios for Sea Level Rise
Central and South Bay

San Francisco Bay  1 m sea level rise  N  0 2 4 8 12 16 Miles

bcdc Map is based on USGS 2m DSM and National Agriculture Imagery Program data. Map is illustrative and depicts a potential inundation scenario in 2100. Limitations in the geospatial data available may effect accuracy. Map should not be used for planning purposes.

## Figure 3

San Francisco Bay Scenarios for Sea Level Rise
South Bay

San Francisco Bay  1 m sea level rise  N  0 0.5 1 2 3 Miles

bcdc Map is based on USGS 2m DSM and National Agriculture Imagery Program data. Map is illustrative and depicts a potential inundation scenario in 2100. Limitations in the geospatial data available may effect accuracy. Map should not be used for planning purposes.

Maps from BCDC. 2007. http://www.bcdc.ca.gov/index.php?cat=56

Map footnote: Limitations in the mapping data may affect accuracy. Therefore, they are illustrative and should not be used for small-scale planning purposes.

Contact: Leslie Lacko, San Francisco Bay Conservation and Development Commission, lesliel@bcdc.ca.gov

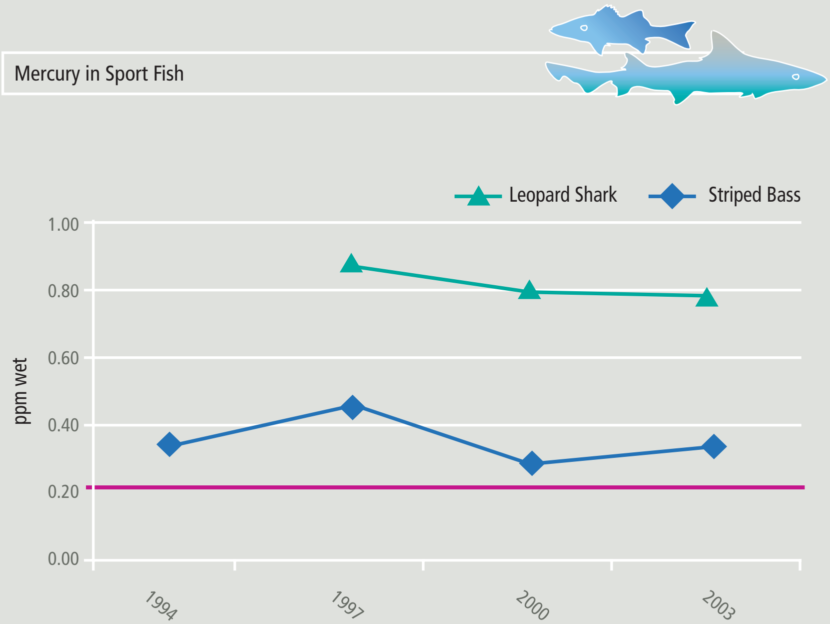
**Sea level rise could affect Bay water quality in coming decades.** Sea level at the Golden Gate is about 7 inches higher today than it was in 1920 (Figure 1). The Intergovernmental Panel on Climate Change and the 2006 California Climate Action Team Report predict that mean sea level will rise between 12 and 36 inches by the year 2100. Rising sea level will impact property owners, critical public infrastructure, and natural resources through submerging land and extending the area prone to flooding. Rising sea level could have an impact on Bay water quality through a variety of mechanisms (for example, submerging potentially contaminated areas, effects on pollutant transport through the Bay, effects on the Bay food web, effects on wetland habitat), but this has not yet been studied. In a sea level rise mapping project, the Bay Conservation and Development Commission identified the shoreline areas likely to be most impacted by sea level rise. They developed maps that illustrate a high impact scenario in which sea level rises 39 inches by the year 2100 (Figures 2 and 3).

# Water Quality Trends at a Glance

## Thumbnail Summaries of Trends in Some of the Most Important Water Quality Indicators for the Bay

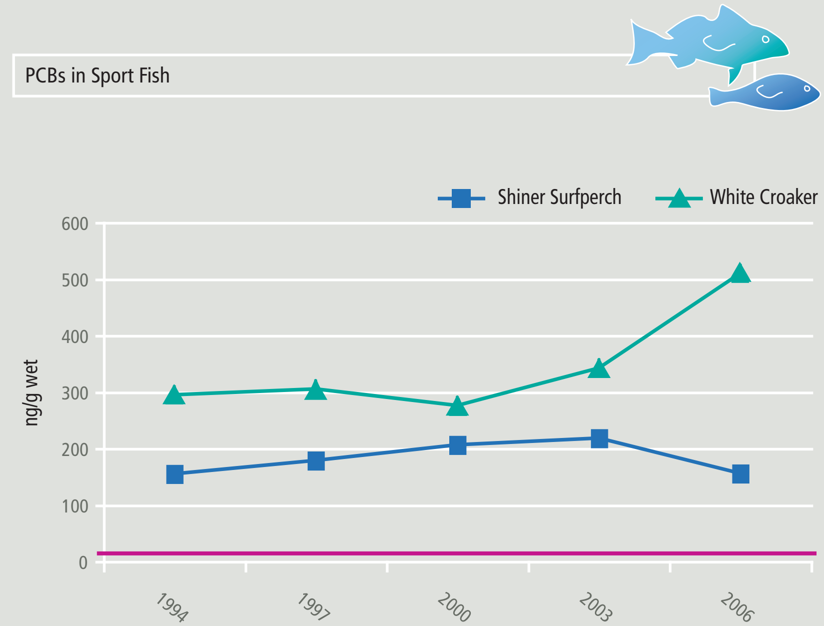



San Francisco Ferry Building. Photograph by Nicole David.




Footnote: Baywide medians. Leopard shark: 90-105 cm. Striped bass: 45-59 cm. Data from the RMP and Fairey et al. (1997).

Contact: Jennifer Hunt, SFEI (jhunt@sfei.org).



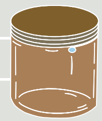

Footnote: Baywide medians. Data from the RMP and Fairey et al. (1997).

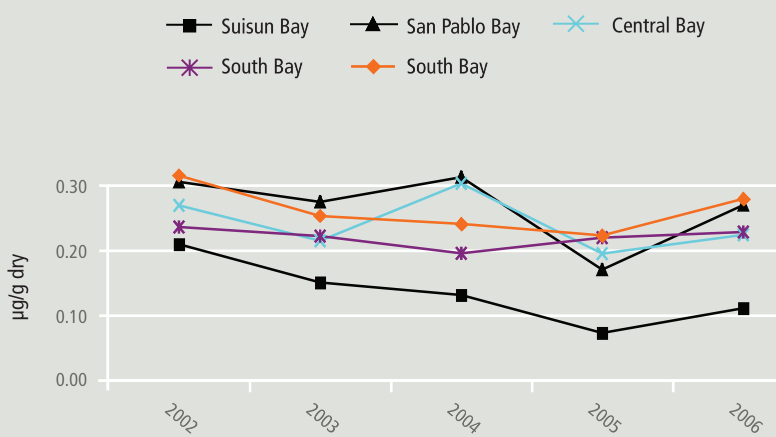
Contact: Jennifer Hunt, SFEI (jhunt@sfei.org).

**Mercury in Sport Fish.** Leopard shark and striped bass are the two species that accumulate the highest concentrations of mercury and are therefore important indicators of mercury impairment. Mercury concentrations have shown some variation, but no clear long-term trend. Red line indicates TMDL target for sport fish tissue (0.2 ppm). Data for 2006 were not available at the time this report was printed.

**PCBs in Sport Fish.** White croaker and shiner surfperch are sport fish species that accumulate high concentrations of PCBs and are consequently important indicators of PCB impairment. Concentrations in white croaker in 2006 were the highest observed since monitoring began in 1994. In contrast, concentrations in shiner surfperch were among the lowest observed. The causes of these patterns are unknown. Red line indicates the TMDL target for white croaker (10 ng/g).

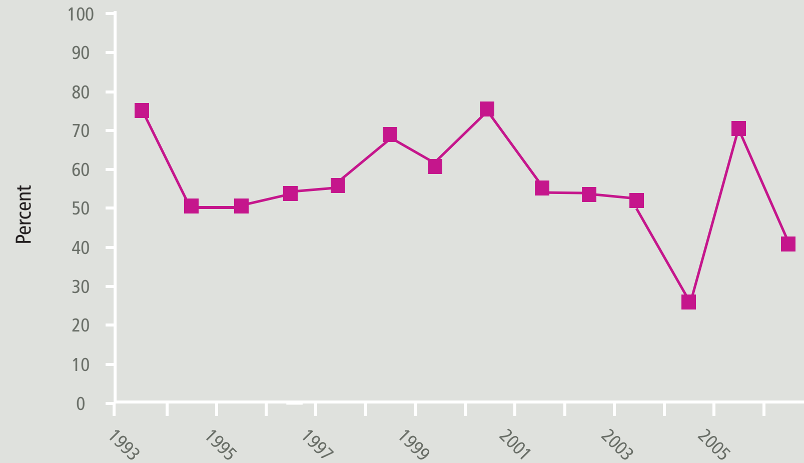
## Total Mercury in Sediment






Contact: Sarah Lowe, SFEI (sarahl@sfei.org).

## Percent Toxic Sediment Samples



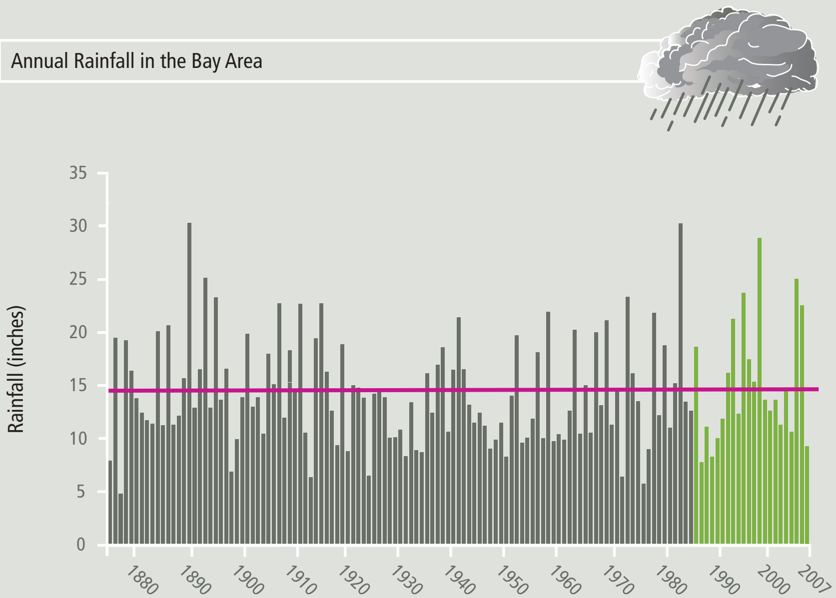

Footnote: Sediment samples are tested using amphipods and mussel larvae.

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

**Annual Average Total Mercury in Sediment by Bay Segment.** In 2002, the RMP began sampling in a manner that yields representative average concentrations for each Bay segment. The lowest concentrations for four of five segments were observed in 2005, but were higher in each segment in 2006. Mercury concentrations in sediment appear to have declined since the RMP began in 1993.

**Percent of RMP Sediment Samples Causing Toxicity in Lab Tests.** The frequent occurrence of toxic sediment samples in the Estuary is a major concern. In every year since sampling began in 1993, 26% or more of sediment samples have been determined to be toxic to one or more test species. No long-term decrease or increase is apparent from these data.

## Annual Rainfall in the Bay Area

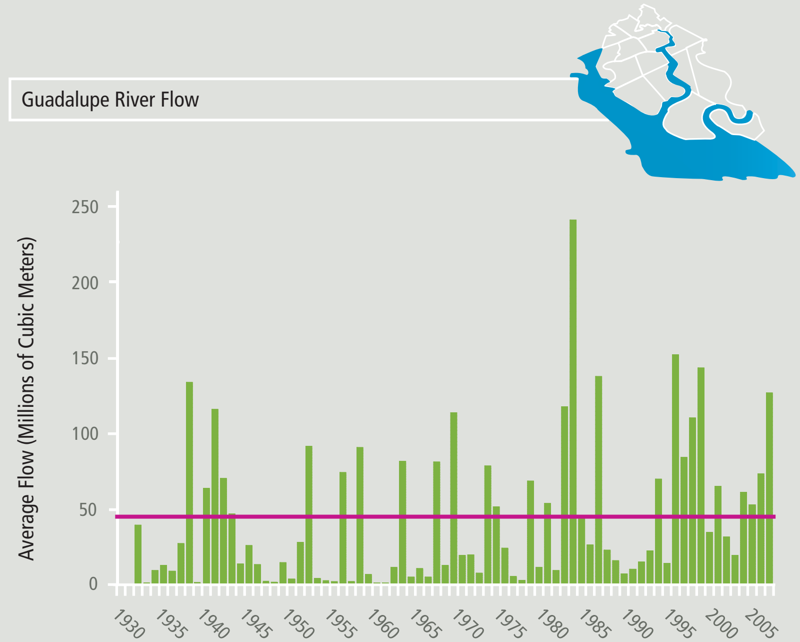



Footnote: Annual rainfall measured at San Jose shown as index for Bay Area rainfall.Green bars coincide with RMP monitoring.

Horizontal line indicates long-term average (14.4 inches per year)

Source: Jan Null, Golden Gate Weather Services.

## Guadalupe River Flow



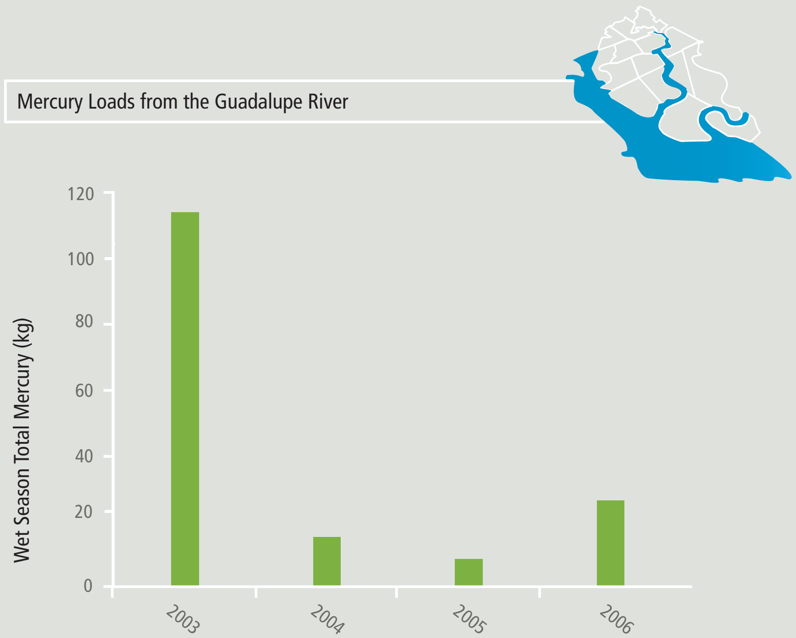

Source: U.S. Geological Survey.

Horizontal line indicates long-term average (44 million cubic meters)

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

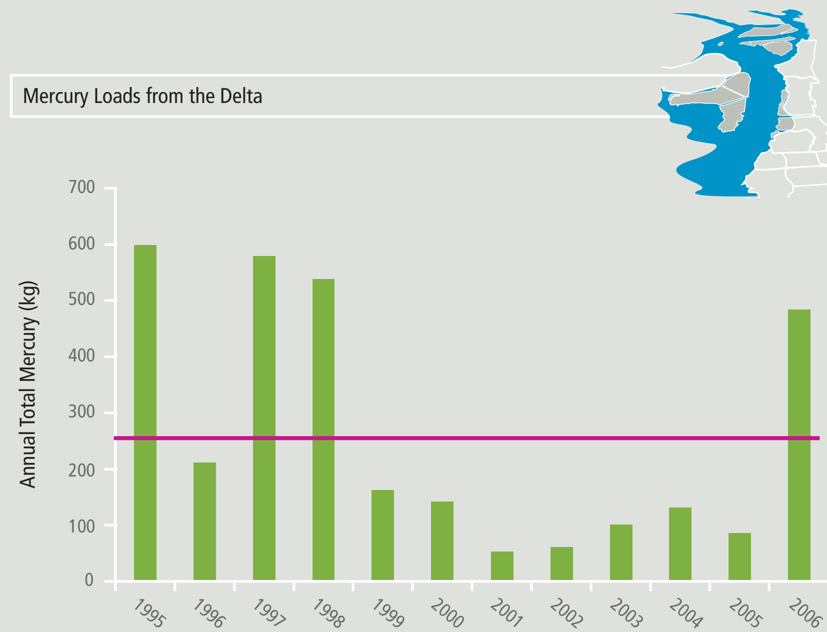
**Annual Rainfall in the Bay Area.** An index of freshwater flow into the Bay, which has a large influence on pollutant transport into the Bay and general water quality in the Bay. Freshwater flow fluctuates widely from year to year, making it more challenging to measure trends in pollutant inputs and water quality. Records for San Jose date back to 1875.

**Annual Average Flow from the Guadalupe River.** Stormwater flows are a primary influence on loads from local Bay Area watersheds. Flows from the Guadalupe River, a major contributor of mercury to the Bay, were relatively high from 1995 through 1998, and at or below the long-term average from 1999 through 2004. The average flow for 2006 (127 million cubic meters) was relatively high – the third highest observed in the course of the RMP and the sixth highest since 1932. Year to year variation in flow from the Guadalupe watershed is a rough index of variation in flows from other local watersheds.




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.

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




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

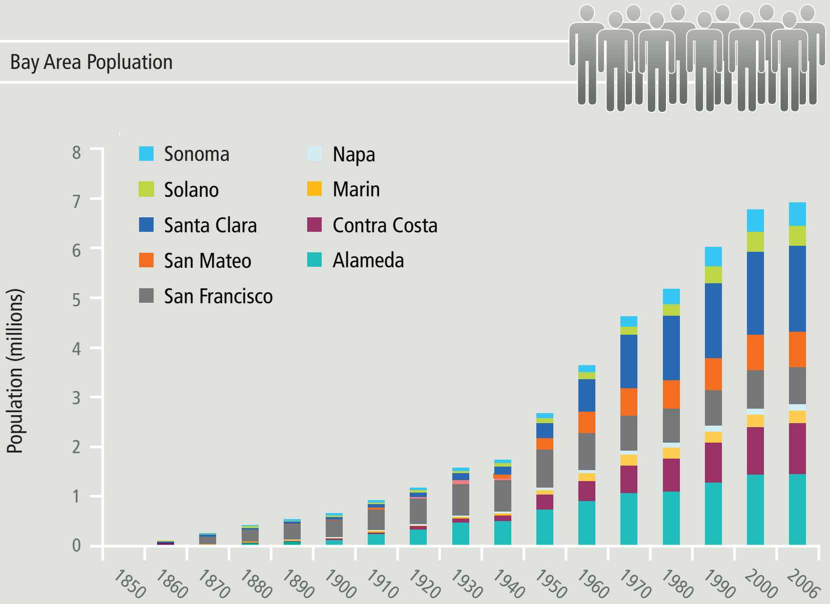
Average (1995-2006) = 262 kg/yr

Contact: Nicole David, SFEI (nicoled@sfei.org).

**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 selected for 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 and many small magnitude floods that did not transport a large amount of mercury. The present estimate of long-term average loads for the period 1977-2006 is 129 kg/yr.

**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. A RMP study has allowed estimation of loads from 1995 to present. Sampling conducted during the high flows of January 2006 helped to refine the estimates, which had been significantly underestimated previously due to a lack of information on high-flow events. Loads in 2006 were relatively large due to high flows on the Sacramento River and the Yolo Bypass.

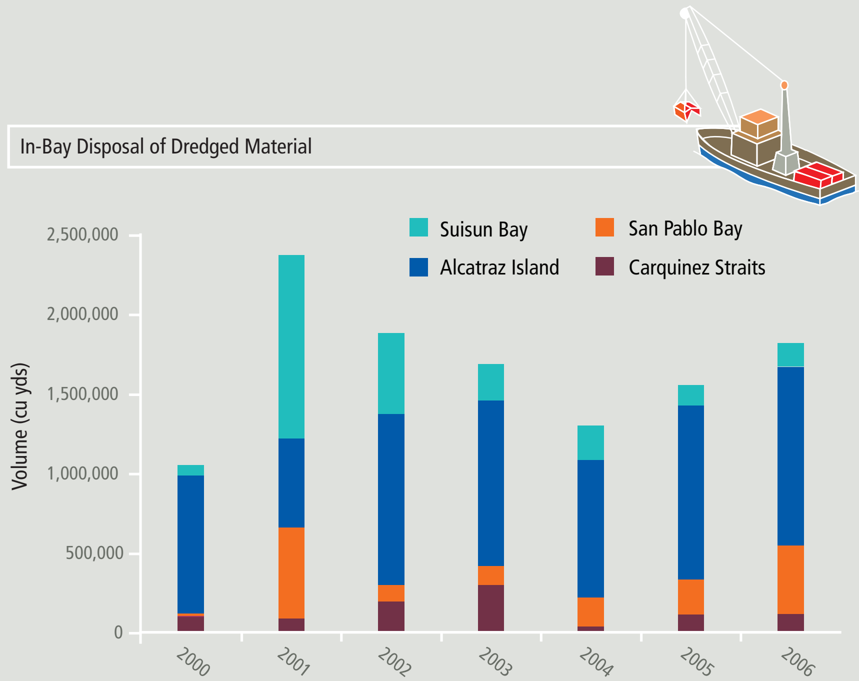
Bay Area Popluation




Footnote: Data from the Association of Bay Area Governments and U.S. Census Bureau. 2006 values are estimates from http://factfinder.census.gov.

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

In-Bay Disposal of Dredged Material



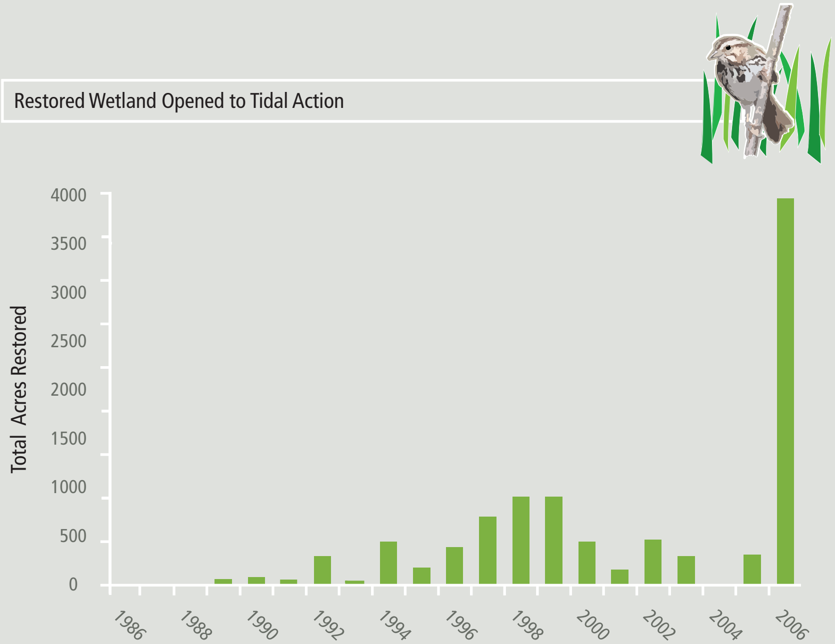

Footnote: Data from the U.S. Army Corps of Engineers.

Contact: Katie Harrold, SFEI (katie@sfei.org).

**Bay Area Population.** The large and growing human population of the Bay Area places continuing pressure on Bay water quality through increases in wastewater volume, urbanization, vehicle usage, and other mechanisms. The population of the Bay Area reached 6.8 million in 2000, and is predicted to increase by another million by 2020. The estimated population in 2006 was 6.9 million.

**Annual Volume of Dredged Material Disposed of in the Bay.** Dredged material disposal is one of the pathways for pollutant redistribution within the Bay. In 2006, 1.8 million cubic yards of dredged material were disposed of at the four disposal sites in the Bay. Other dredged material was disposed of in the ocean and used in restoration projects in upland areas. Dredged material management agencies plan to reduce in-Bay disposal to 1 million cubic yards per year in the next 10 years.

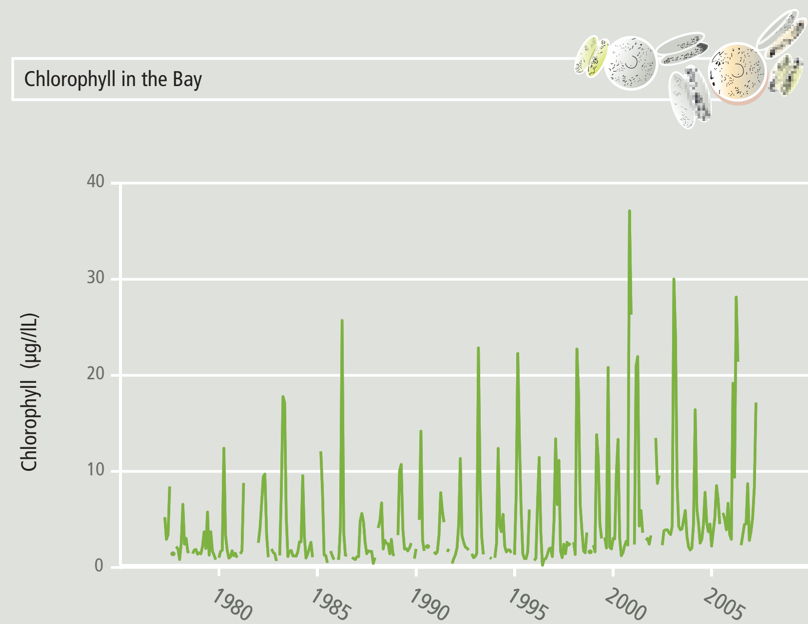
## Restored Wetland Opened to Tidal Action




Footnote: Data from the Bay Area Wetland Tracker (www.wetlandtracker.org).

Contact: Josh Collins, SFEI (josh@sfei.org).

## Chlorophyll in the Bay




Footnote: 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://sf-bay.wr.usgs.gov/access/wqdata/). Graph prepared by Alan Jassby, U.C. Davis, adjassby@ucdavis.edu.

Contact: James Cloern, U.S. Geological Survey, jecloern@usgs.gov

**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 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, and several other major tidal wetland restoration projects. These projects could have a significant influence on Bay water quality, with the potential for increased mercury in the food web a particular concern. The number of acres restored increased sharply in 2006.

**Annual and Seasonal Trends in Phytoplankton Biomass.** Since the late 1990s, significant changes in phytoplankton population dynamics in San Pablo, Central, and South bays 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 concentration from one monitoring location shows an increase in baseline chlorophyll (the minimum value each year) and occurrences of autumn/winter blooms in the past decade.

# Feature Articles

## The big picture of water quality in the Estuary

# The State of the Bay: Water Quality

Jay Davis and Mike Connor, San Francisco Estuary Institute
Russ Flegal, University of California, Santa Cruz

## Highlights

*A pictorial summary of water quality in San Francisco Bay is presented that includes enough detail to be an accurate reflection of reality and the wealth of information available, yet readily understood*

*The Clean Water Act and other environmental laws over the past 35 years have largely solved serious problems related to organic waste, nutrients, and silver contamination*

*Several significant water quality threats remain, including mercury, PCBs, dioxins, and exotic species*

*The forecast for PCBs and dioxins is for slow progress toward recovery over the next 20 years*

*For mercury and exotic species, improvement is conceivable if effective management actions can be implemented, but further deterioration is also possible in the absence of such actions*

*The outlook for another group of pollutants – selenium, legacy pesticides, PAHs – is a bit brighter, with a better chance of falling below risk thresholds in 20 years*

*Concern for other pollutants – PBDEs, pyrethroids, sediment toxicity, and pollutant mixtures – is growing, either due to increasing rates of input into the Bay or advances in understanding*

View of the Bay from the Golden Gate Bridge. Photograph by Jay Davis.

Terms in **Blue** defined in Glossary on Inside Back Cover



# How is the Bay Doing?

The mission of the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) is to provide the information needed by policy makers, water quality managers, and the public to make decisions about stewardship of this magnificent ecosystem. The RMP and other programs collect a wealth of information on the alphabet soup of chemicals that pervades the waters of the Bay, their sources and pathways of entry, their cycling within the ecosystem, and the health threats they pose to wildlife and humans. To be useful to policy makers and the public, this complex mass of data must be boiled down to brief and understandable statements about the condition of the Bay. People need as simple an answer as possible to the question: "How is the Bay doing?"

The state of water quality in the Bay cannot be accurately summarized in a single score, grade, word, phrase, or sentence. The complex mixture of substances in Bay waters includes pollutants that vary in the severity of the problem they pose, their origins, their geographic distribution, and their trajectories of improvement or deterioration. It is possible, however, to present this information in a concise and simple summary that retains enough detail to be an accurate reflection of reality, while being readily understood by all.

In the past three years the RMP and the Clean Estuary Partnership (CEP) have sponsored technical reviews of the state of knowledge of many pollutants of concern in the Bay. The reviews have been published in the form of Conceptual Model and Impairment Assessment Reports by the CEP (**Table 1**) and as articles in a special issue of the journal Environmental Research by RMP investigators and collaborators (**Table 2**). These reviews were able to draw on the rich datasets created by the RMP, the U.S. Geological Survey, and other programs that make the Bay one of the most, perhaps the most, thoroughly monitored estuaries in the world (Sañudo-Wilhelmy et al. 2004).

**Table 1**
**CEP Conceptual Model and Impairment Assessment Reports**

**The reports are available at www.cleanestuary.org/publications/index.cfm.**

| Report | Publication Date |
|---|---|
| Legacy Pesticides | 2004 |
| Copper and Nickel | 2005 |
| Diazinon/Toxicity | 2005 |
| Dioxins | 2005 |
| Mercury | 2006 |
| PCBs | 2006 |
| Selenium | 2005 |

This article provides a brief, nontechnical summary of the information compiled in the 7 CEP reports and the 11 journal articles, which in turn summarized hundreds of other reports and thousands and thousands of water quality data points. Having this information in hand affords an excellent opportunity to provide an assessment of the current state of water quality in the Bay.

# Bay Water Quality at a Glance

**Tables 3 - 7** provide a pictorial summary of the current state of knowledge for the pollutants of primary concern in San Francisco Bay. For each pollutant, information for six subject areas is summarized: the severity of the problem ("Status"), the nature of the risks to humans and wildlife health ("Health Risks"), where the pollutant is coming from ("Important Pathways"), areas that are particularly polluted ("Spatial Pattern"), trends in recent decades ("Recovery Trend"), and what is expected for the future based on existing information ("Likely Status in 20 Years"). These six areas correspond to the major topics that the RMP is designed to study (Hoenicke 2005).

## Problems Solved

Bay water quality has improved dramatically since the passage of the Clean Water Act in 1972. Prior to 1972, severe dissolved oxygen depletion due to inputs of organic waste and nutrients was a common occurrence, causing fish kills, foul odors, and other water quality problems. The Clean Water Act provided clear goals and over a billion dollars for construction of Bay Area wastewater treatment facilities, resulting in improved wastewater treatment that sharply reduced the loading of organic waste, nutrients, and other pollutants (**see page 7**). Other important management actions in the 1970s and 1980s included bans on many pollutants, including PCBs, DDT, dieldrin, and chlordane. Significant changes in industrial and military activity also occurred over the past few decades, including the closing of many military facilities and polluting industries (notable examples are a lead smelter and a photo processing plant), and the cessation of mining activity.

As a result of these actions and changes, the most serious water quality problems that were recognized in the 1970s have largely been solved (**Table 3**). RMP monitoring has documented a general trend of steadily increasing dissolved oxygen and elimination of low-oxygen conditions in response to reduced inputs of organic waste and nutrients over the past few decades (Cloern et al. 2003). Fish kills are no longer a common occurrence in the Bay. Toxic pollutants have also generally declined since the period of peak contamination in the 1950s and 1960s (van Geen and Luoma 1999), and some have fallen to concentrations that are considered not to pose significant health risks to humans or aquatic life. For example, in the 1970s the Bay had the highest silver concentrations recorded for any estuary in the world, but the closure of a major photo processing plant and improved wastewater treatment led to a reduction in concentrations in South Bay clams from 100 ppm in the late 1970s to 3 ppm in 2003, eliminating adverse impacts on clam reproduction.

Concerns about these problems have not been entirely eliminated. Recent increases in the growth of algae in the Bay suggest that impacts could occur if nutrient loading to the Bay escalates. Low dissolved oxygen resulting indirectly from the large amount of freshwater input to the Bay in 2006 was considered a possible cause of a fish kill in June of that year. Dissolved oxygen and nutrient concerns still exist for salt ponds, lagoons, and other areas around the edges of the Bay. However, with the continued vigilance of regulators and treatment plant operators, broad-scale adverse impacts of dissolved oxygen, nutrients, and silver on Bay water quality are not likely.

## The Bay's "Most Wanted"

Water quality managers maintain an official list of the pollutants that are considered to be causing unacceptable adverse impacts on the Bay. This list is known as the "303(d) List", because development of the list is a requirement of Section 303(d) of the Clean Water Act (**see page 30** for more on the 303(d) List). The status for each pollutant shown in **Tables 3 - 7** is derived from the most recent version of the 303(d) List (SFBRWQCB 2006).

Four pollutants – mercury (total mercury and methylmercury), PCBs, dioxins, and exotic species – are classified as having the most severe impacts on Bay water quality because the entire Bay is considered impaired by these pollutants, and the degree of impairment is well above established thresholds of concern.

Mercury is Bay water quality enemy number one. Mercury is a primary driver of the fish consumption advisory for the Bay, and also is suspected to be adversely affecting wildlife populations, including the endangered California Clapper Rail. Due to these concerns, the first TMDL for the Bay has been developed for mercury. Mercury has two entries in **Table 4**, total mercury and methylmercury, because these two different forms present very different opportunities for management.

Total mercury is the sum of all of the different forms of mercury in the environment. Total mercury is easy to monitor, and its sources, distribution, and trends are relatively well understood. Total mercury is persistent, is largely bound to sediment particles that are efficiently trapped within the Bay, and is distributed so widely throughout the Bay-Delta and its watershed that it will take many decades for total mercury concentrations to decline significantly.

Methylmercury typically represents about 1% of total mercury, but is the form that accumulates in aquatic life and poses health risks to humans and wildlife. Methylmercury is a neurotoxicant, and is particularly hazardous for fetuses and children and early life-stages of wildlife species as their nervous systems develop. In contrast to total mercury, methylmercury is not persistent, and its concentrations are highly variable over small intervals of time and space and do not closely correspond with total mercury concentrations. The sources of methylmercury in the Bay, particularly the methylmercury that actually gets taken up into the food web, are not well understood. Methylmercury concentrations in the Estuary (as indicated by accumulation in striped bass) have been relatively constant since the early 1970s, but could quite plausibly increase, remain constant, or decrease in the next 20 years. Wetlands are often sites of methylmercury production, and restoration of wetlands in the Bay on a grand scale is now beginning, raising concern that methylmercury concentrations could increase across major portions of the Bay. However, methylmercury cycling is not yet well understood, and recent findings suggest that some wetlands actually trap methylmercury and remove it from circulation. Consequently, with improved understanding of methylmercury dynamics in the Bay, approaches might be found that would prevent increases in methylmercury concentrations, or *possibly* even reduce concentrations and associated health risks in the next 20 years.

Other pollutants on the most wanted list are PCBs, dioxins, and exotic species. Like total mercury, PCBs are highly persistent, bound to sediment particles, and widely distributed throughout the Bay and its watershed. PCBs reach high concentrations in humans and wildlife at the top of the food chain where they can cause developmental abnormalities and growth suppression, endocrine disruption, impairment of immune system function, and cancer. PCB concentrations in sport fish are more than 10 times higher than thresholds of concern for human health and are, along with mercury, a primary driver of the fish consumption advisory for the Bay. There is also concern for the effects of PCBs on wildlife, including species like harbor seals at the top of the Bay food web and sensitive organisms such as young fish. General recovery of the Bay from PCB contamination is likely to take many decades because the rate of decline is slow and concentrations are so far above the threshold for concern. One bright spot is Suisun Bay, where present concentrations are not as high and should be below the threshold in 20 years.

**Table 2**
**Articles in the special issue of Environmental Research, to be published in September 2007.**

| |
|---|
| Copper |
| Effects of pollutants |
| Emerging pollutants |
| Legacy pesticides |
| Mercury |
| Nickel |
| PAHs |
| PCBs |
| Sediment toxicity |
| Sediment |
| Silver |

The human and wildlife health risks of dioxins are similar to those for PCBs. Dioxins have not received as much attention from water quality managers because there are no large individual sources in the Bay Area and concentrations in the Bay are among the lowest measured across the U.S. Nevertheless, concentrations in sport fish are well above the threshold for concern and the entire Bay is included on the 303(d) List. Dioxins are similar to PCBs in their persistence and distribution throughout the Bay and its watershed, and are unlikely to decline significantly in the next 20 years.

Exotic species represent a different form of pollution that is included on the 303(d) List. San Francisco Bay is considered the most highly invaded estuary in the world. Nonnative species introduced to the Bay have reduced or eliminated populations of many native species (so that in some regions and habitats virtually 100% of the organisms are introduced), disrupted food webs, eroded marshes, and interfered with fishing, boating, and water contact recreation. Recently adopted state ballast discharge regulations to be phased in over 2009-2016, if rigorously implemented and enforced, would essentially resolve one major pathway for exotic species.

## Other Pollutants of Concern

Three pollutants – selenium, legacy pesticides (currently banned pesticides that were used in the past and still persist in the environment, including the insecticides DDT, dieldrin, and chlordane), and PAHs – are also of concern, because either the entire Bay or several Bay locations are included on the 303(d) List and concentrations are above established thresholds of concern.

Selenium accumulates in Bay diving ducks to concentrations that pose a potential health risk to humans who eat them, and have caused a consumption advisory for ducks to be issued. Selenium concentrations also pose a threat to wildlife in the Bay. Recent studies suggest that selenium concentrations may be high enough to cause deformities, growth impairment, and mortality in early life-stages of Bay fish species. The major pathways of selenium input into the Bay are outflow from the Delta and industrial and municipal wastewater effluent. While the amount of selenium discharged by Bay Area refineries has been reduced significantly in the past 15 years, concentrations in the Bay do not show an increasing or decreasing trend. A TMDL for selenium is in the planning stages. The future status of the Bay with respect to selenium is unclear primarily due to uncertainty regarding the management of selenium-laden agricultural runoff from the San Joaquin Valley, which has a very large influence on selenium concentrations in the north Bay.

The entire Bay is on the 303(d) List for legacy pesticide contamination. Legacy pesticides were one of the drivers of the fish consumption advisory issued in the early 1990s. Concentrations in the Bay have been slowly but steadily falling since these chemicals were banned in the 1970s and 1980s. In recent sampling, very few sport fish samples have exceeded thresholds of concern for these chemicals. Given the observed pattern of decline, in 20 years it is likely that no sport fish will exceed thresholds.

PAHs (polycyclic aromatic hydrocarbons) are included on the 303(d) List for several Bay locations. There is also concern that PAH concentrations in sediment across much of the Bay exceed a threshold for potential impacts on early life stages of fish. PAH concentrations over the past 20 years have held fairly constant. Increasing population and motor vehicle use in the Bay Area are cause for concern that PAH concentrations could increase over the next 20 years. On the other hand, PAH concentrations in Bay Area air have declined over the past ten years, and if PAH inputs to the Bay can be decreased concentrations are expected to drop quickly.

## Below Thresholds But Carefully Watched

Two heavy metals – nickel and copper – are below thresholds of concern in the Bay. These metals have received a great deal of attention from water quality managers. In the 1990s copper and nickel were major concerns in the Bay, as concentrations were frequently above the water quality objectives in effect at that time. An evaluation of the issue by the Water Board and stakeholders led to new water quality objectives for copper and nickel in the Lower South Bay which are less stringent but still considered fully protective of aquatic life, and the removal of copper from the 303(d) List in 2002 (page 79). Portions of the Bay (including the Petaluma River, San Pablo Bay, and Suisun Bay) remained on the 2006 303(d) List for nickel, but this was based on comparison with the now superseded old Basin Plan objective for total nickel. Along with the new objectives for Lower South Bay, a program has been established to guard against future increases in concentrations in the Bay. The program includes actions to control known sources in wastewater, urban runoff, and use of copper in shoreline lagoons and on boats. More aggressive actions to control sources can be triggered by increases in copper or nickel concentrations.

## Rising Concerns

PBDEs, pyrethroids, sediment toxicity, and pollutant mixtures are classified as rising concerns because while water quality objectives have not yet been established for these pollutants in order to place them on the 303(d) List, there is a significant amount of concern about their impacts on the Bay.

PBDEs (polybrominated diphenyl ethers), a class of bromine-containing flame retardants that was practically unheard of in the early 1990s, increased rapidly during that decade and are now ubiquitous in the Bay. Concentrations of PBDEs in humans and wildlife in the Bay Area are among the highest that have been reported in the world. The body of evidence on the toxic effects of PBDEs is growing. USEPA is expected to establish a threshold for concern for PBDEs soon, and this would provide a basis for evaluating the need for fish consumption advice and 303(d) listing. The California Legislature banned the use of two types of PBDE mixtures in 2006. A third major type of PBDE, known as "deca", is still commercially produced. PBDEs are persistent, but appear to be less so than PCBs, so concentrations would be expected to decline once releases to the environment are reduced. Tracking the trends in these chemicals will be extremely important to determine the rate of decline as a result of the ban and if further management actions are necessary to accelerate recovery.

Pyrethroid insecticide use in agriculture, pest control around homes and other buildings, and backyard applications has increased in recent years as the use of organophosphate pesticides has declined. Fish and aquatic invertebrates are quite sensitive to pyrethroids, raising concern for possible impacts on non-target species in aquatic environments. Pyrethroids have been found in sediment samples across wide areas of California, in both agricultural and urban watersheds, and have often been linked to toxicity observed in sediment toxicity tests. Pyrethroids are also under suspicion as a factor involved in the "pelagic organism decline", or "POD", which refers to the sharply reduced abundance of several important fish species in the Estuary in the past few years (page 46). Fortunately, pyrethroids are not persistent, so if their use is curtailed they would quickly cease to be a threat to Bay water quality. Whether such a reduction will occur, however, is unclear.

Sediment toxicity in the Bay is a problem that has persisted since the RMP began performing sediment toxicity tests in 1993. In every year since 1993, 26% or more of sediment samples have been determined to be toxic to one or more test species (page 53). The toxicity tests indicate that pollutant concentrations in Bay sediments are high enough to affect the abundance of aquatic invertebrates. With plans for implementation of sediment quality objectives for the Bay in the next few years (page 45), these observations will begin to drive regulatory decisions. The pollutants causing this persistent toxicity have not yet been identified, and until they are, this problem is likely to persist into the future.

Organisms in the Bay are simultaneously exposed to a complex mixture of hundreds of chemicals. However, due to the difficulty of evaluating multiple chemicals at once, the vast majority of studies of pollutant effects on aquatic life have examined one chemical at a time. In spite of the lack of information on this topic, there is concern that pollutant mixtures could be combining to impair the health and reproduction of Bay wildlife. Pollutant mixtures could be affecting the early life stages of fish that are in decline, such as Delta smelt or striped bass. Mixtures could also be responsible for the Bay's persistent sediment toxicity, as well as impacts on Bay species from invertebrates on up to harbor seals and other species, including humans, at the top of the food web. However, there are many unknowns on this subject, including whether mixtures are having impacts on human and wildlife health, and, if they are, the sources of the key chemicals, spatial patterns and long-term trends, whether the problem is likely to persist into the future, and how to best address the problem.

# A Short Answer

The Bay contains a complex soup of pollutants that vary in the severity and types of risks they pose, and in their sources, spatial distributions, and trends over time. Enforcement of the Clean Water Act and other environmental laws over the past 35 years has resulted in tremendous improvements in overall Bay water quality, solving serious problems related to organic waste, nutrients, and silver contamination.

Several significant water quality threats still remain, however, including mercury, PCBs, dioxins, and exotic species. The forecast for PCBs and dioxins is for slow progress toward recovery over the next 20 years, with concentrations likely to remain above risk thresholds. The outlook for mercury is unclear, and depends on whether effective management actions can be identified and implemented. For exotic species, the rate of introductions could be reduced significantly through management actions.

The future looks brighter for other pollutants (selenium, PAHs and legacy pesticides) whose concentrations do not exceed risk thresholds by much or at all, or it is not entirely clear if they pose significant risks in the Bay at present concentrations. Concentrations of selenium and PAHs could fall below risk thresholds in 20 years depending on management of sources. For legacy pesticides, concentrations should fall below risk thresholds in 20 years through natural breakdown, with lingering concerns only for effects in combination with other pollutants. For nickel and copper, concentrations are below thresholds and management plans are in place to make sure they stay there.

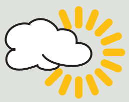
Concern for another group of pollutants is growing, due to either increasing rates of input into the Bay or advances in scientific understanding of the magnitude of specific water quality threats. For PBDEs and pyrethroids the 20-year outlook is currently unclear, and will depend heavily upon management decisions. Concentrations of both of these pollutants would be expected to drop rapidly in response to reduced inputs to the Bay. If use of these chemicals is curtailed, the RMP should be looking ahead to evaluate the risks associated with the next generation of popular flame-retardants and insecticides, which hopefully will be less of a threat to Bay water quality. The outlook for sediment toxicity will be unclear until the causes of this toxicity can be identified. Too many unknowns surround the issue of risks due to pollutant mixtures to characterize current status, much less the status in 20 years.

Continued monitoring and advances in scientific understanding will be essential in refining the forecasts for the Bay's assortment of pollutants of concern, and in tracking the response of the ecosystem to management actions taken to continue the general trend toward improvement of Bay water quality that has occurred over the past several decades.

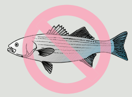
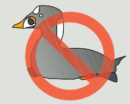
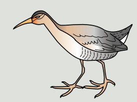
Feature Articles

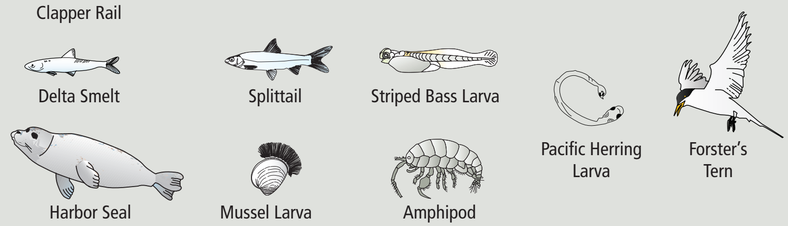
# Legend for Tables 3-7

## Regulatory Status: Corresponds to 303(d) List Status

| | |
|---|---|
|  | The entire Bay is on the 303(d) List, and concentrations are much higher than existing water quality objectives or thresholds for concern |
|  | The entire Bay is on the 303(d) List, and concentrations are slightly above existing water quality objectives or thresholds for concern |
|  | Portions of the Bay are on the 303(d) List, and concentrations are near existing water quality objectives or thresholds for concern |
|  | Not included on the 303(d) List, and concentrations are below existing water quality objectives or thresholds for concern |
|  | Water quality objectives do not exist, so not included on the 303(d) List, but concern does exist for water quality impacts |

## Health Risks

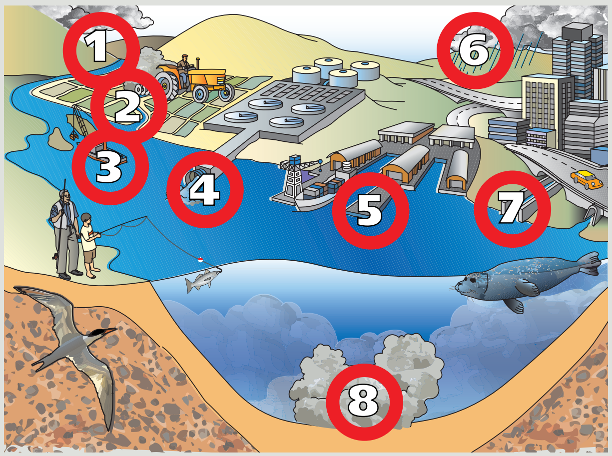
| | | |
|---|---|---|
|  | Primary driver of fish consumption advisory | Human |
|  | Secondary driver of fish consumption advisory | Human |
|  | Primary driver of duck consumption advisory | Human |
| PENDING | Human health threshold under development by USEPA | Human |
|  Clapper Rail | Significant risk to wildlife. Species shown indicates those considered at greatest risk for each pollutant based on existing information. | Wildlife |



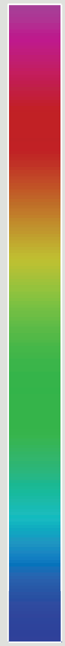
## Legend for Tables 3-7

### Largest Pathways

1 Delta outflow  2 nonurban runoff
3 dredging and dredged material disposal
4 wastewater effluent
5 in-Bay contaminated sites  6 atmospheric deposition
7 urban runoff  8 remobilization from sediment




### Spatial Pattern

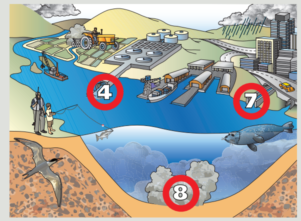
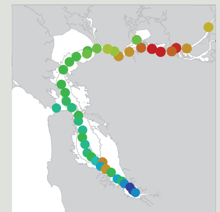
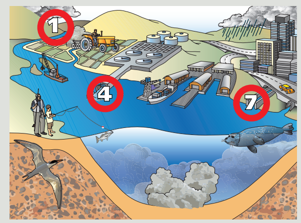
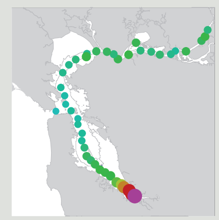
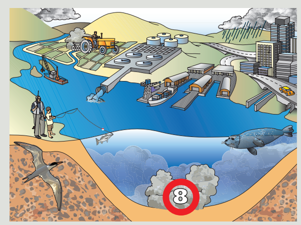
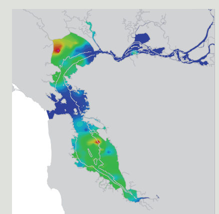



### Recovery Trend: Describes long-term trends towards recovery in recent decades

| | |
|---|---|
| ↗ | Significant improvement in recent decades |
| ↗ | Slow improvement in recent decades |
| → | No improvement or deterioration in recent decades |
| ↘ | Slow deterioration in recent decades |
| ↘ | Significant deterioration in recent decades |

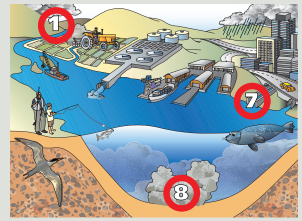
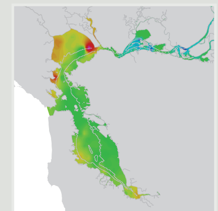
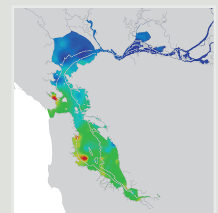
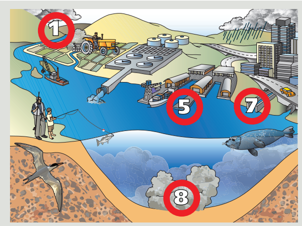
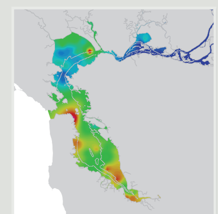
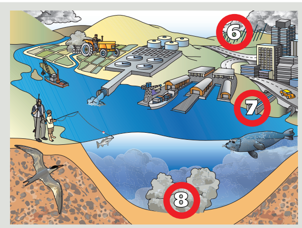
?
Too little information available or unclear

**Table 3**
**Water Quality in San Francisco Bay: Problems Solved**

| Pollutant | Status | Health Risks | Important Pathways | Spatial Pattern | Recovery Trend | Likely Status in 20 Years |
|---|---|---|---|---|---|---|
| Organic Waste (oxygen depletion) |  | Effects not likely |   |  |  |  |
| Nutrients |  | Effects not likely |   |  |  |  |
| Silver |  | Effects not likely |   |  |  |  |

Spatial patterns shown for dissolved oxygen in water, nitrate and nitrite in water, and silver in water.

**Table 4**
**Water Quality in San Francisco Bay: The Biggest Water Quality Problems**

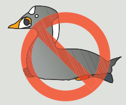
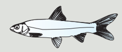
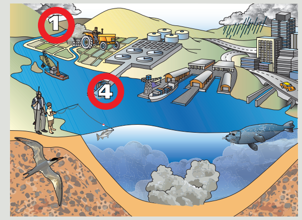
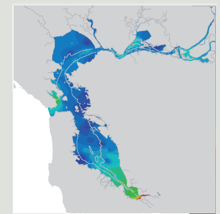
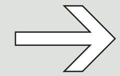
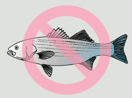
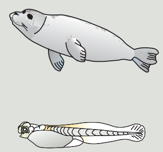
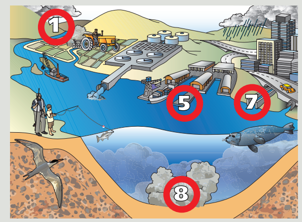
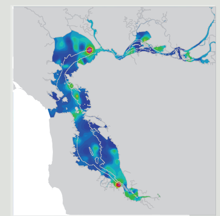
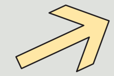
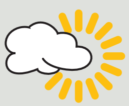
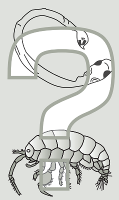
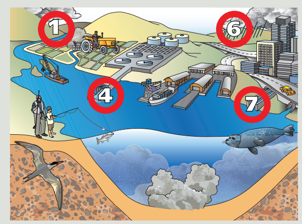
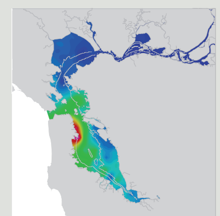
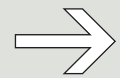
| Pollutant | Status | Health Risks (Humans / Wildlife) | Important Pathways | Spatial Pattern | Recovery Trend | Likely Status in 20 Years |
|---|---|---|---|---|---|---|
| Total Mercury | | |  |  | | |
| Methylmercury | | | ? |  | | |
| PCBs | | |  |  | | |
| Dioxins | | |  | ? | ? | |
| Exotic Species | | Major impacts on virtually all types of invertebrates and some fish; possible impacts on some birds. So far only minor human health problems. | Ship ballast water<br>Ship and boat hull fouling<br>Bait imports and transfers | Except near the mouth of the Bay, common and dominant on hard and soft substrates and common in the water column. | | |

Spatial patterns shown for total mercury in sediment, methylmercury in sediment, and PCBs in sediment.



Feature Articles

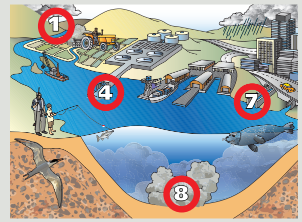
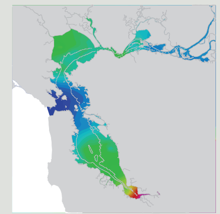
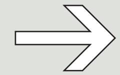
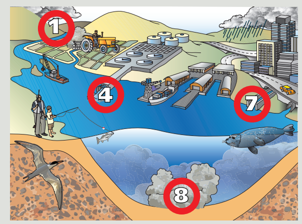
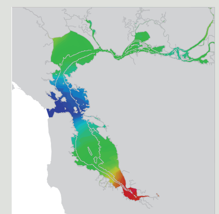
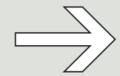
**Table 5**
**Water Quality in San Francisco Bay: Other Threats**

| Pollutant | Status | Health Risks | | Important Pathways | Spatial Pattern | Recovery Trend | Likely Status in 20 Years |
|---|---|---|---|---|---|---|---|
| | | Humans | Wildlife | | | | |
| Selenium |  |  |  |   |  |  |  |
| Legacy Pesticides (DDT, dieldrin, and chlordane) |  |  |  |   |  |  |  |
| PAHs |  | |  |   |  |  |  |

Spatial patterns shown for total selenium in water, DDT in sediment, and PAHs in sediment.

**Table 6**

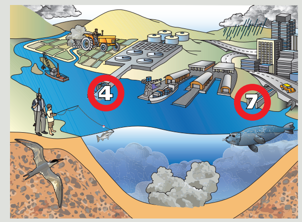
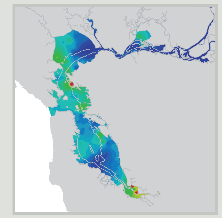
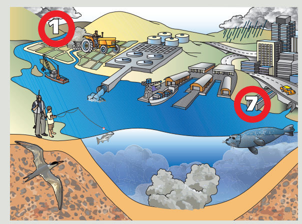
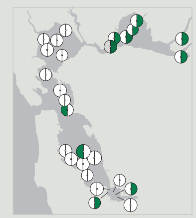
**Water Quality in San Francisco Bay: Below Thresholds But Carefully Watched**

| Pollutant | Status | Health Risks (Humans / Wildlife) | Important Pathways | Spatial Pattern | Recovery Trend | Likely Status in 20 Years |
|---|---|---|---|---|---|---|
| Nickel |  | Effects not likely |  |  |  |  |
| Copper |  |  |  |  |  |  |

Spatial patterns shown for dissolved nickel in water and dissolved copper in water.

Feature Articles

**Table 7**
**Water Quality in San Francisco Bay: Rising Concerns**

| Pollutant | Status | Health Risks: Humans | Health Risks: Wildlife | Important Pathways | Spatial Pattern | Recovery Trend | Likely Status in 20 Years |
|---|---|---|---|---|---|---|---|
| PBDEs | FOG | PENDING | |  |  | ↘ | ? |
| Pyrethroids | FOG | | |  | insufficient data | ↘ | ? |
| Sediment Toxicity | FOG | | | ? |  | → | ? |
| Pollutant Mixtures | FOG | | | ? | ? | ? | ? |

Spatial patterns shown for BDE 47 in sediment and toxicity to two test organisms (green shaded semicircles indicate significant toxicity to one of the species) in samples from 2006.

# Trash in San Francisco Bay Area Urban Creeks – Sources, Pathways, Assessments, and Control Measures

Chris Sommers and Paul Randall
Santa Clara Valley Urban Runoff Pollution Prevention Program

Matt Cover, San Francisco Bay Regional Water Quality Control Board

Markley Bavinger, City of Oakland Environmental Services Division

## Highlights

*Trash discarded in Bay Area watersheds, creeks, and San Francisco Bay, continues to be a concern to citizens, municipalities, and water quality regulators due to potential adverse effects to humans, fish, and wildlife*

*Trash originates from sources including pedestrians, vehicles, waste containers, and illegal dumping, and is transported to creeks and the Bay by pathways including stormwater conveyance systems (i.e., storm drains), wind, and direct dumping*

*Results obtained from a Rapid Trash Assessment procedure indicate that large amounts of trash are conveyed via stormwater from poorly kept commercial facilities, schools, bus stops, and roads during the wet season, and wind blown trash from adjacent land uses and illegal dumping on creek banks in the dry season*

*Measures implemented by Bay Area cities and counties to control trash include institutional controls like street sweeping and public education campaigns and structural treatment controls that are effective in capturing trash transported to and from stormwater conveyance systems*

Trash in the Bay. Photograph by Amy Franz.

Terms in **Blue** defined in Glossary on Inside Back Cover



# Trash Impacts on Creeks

Every day, people in the Bay Area dispose of and discard consumer items and waste materials including food and beverage containers (e.g., plastic bags and bottles), cigarette butts, food waste, construction and landscaping materials, furniture, electronics, tires, and hazardous materials (e.g., paint and batteries). While many of these items are properly disposed of, large amounts of debris enters the environment as "trash". Trash has historically been found at high levels at some sites in San Francisco Bay Area watersheds, creeks, and in San Francisco Bay, and continues to be a concern to citizens, municipalities, and water quality regulators.

Once in water bodies, trash can adversely affect humans, fish, and wildlife. Diapers, medical waste (e.g., used hypodermic needles and pipettes), and human or pet waste discarded in water bodies can threaten the health of people who use them for recreation. Additionally, broken glass or sharp metal fragments in streams can cause puncture or laceration injuries. Small and large floatables can inhibit the growth of aquatic vegetation, decreasing spawning areas and habitats for fish and other living organisms. Wildlife living in creeks, rivers and riparian areas can be killed by ingesting or becoming entangled in floating trash (Laist and Liffmann 2000). Trash that settles to the bottom of water bodies can be problematic for organisms living in the sediment of creeks and contribute to sediment contamination. Floating debris that is not trapped or removed will eventually end up on the beaches or in the open ocean, spoiling shoreline areas and degrading coastal waters. Marine mammals, turtles, birds, fish, and crustaceans all are affected by entanglement in or ingestion of floatable debris.


# Defining Trash Sources and Pathways

People are the fundamental source of all trash found in urban creeks and San Francisco Bay. However, similar to other pollutants, more specific sources and associated transport pathways (**Sidebar, next page**) must be identified to allow effective management actions to be implemented. The Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) recently developed a simple conceptual model (**Figure 1**) to better define potential trash sources and transport pathways in urban creeks. Source and pathway categories described are based on creek trash assessments in Santa Clara County and local agency staff knowledge of how trash is deposited and transported to local water bodies.

The conceptual model identifies four distinct source categories for trash to urban creeks. **Pedestrians** who lack the willingness to properly dispose of waste or do not have access to waste containers are likely the greatest source of trash in local water bodies. Land areas where pedestrians litter typically include high foot-traffic locations (e.g., shopping plazas, convenience stores, and parks), transition points (e.g., bus stops, train stations, and entrances to public buildings), and special event venues (e.g., concerts, sporting events, and fairs). Drivers and passengers who litter from **Vehicles** or do not adequately cover their vehicles when transporting trash and debris are also sources. Land areas that may generate trash from vehicles include roads, highways (on- and off-ramps, shoulders, or median strips) and parking lots. Trash sources also include **Waste Containers** (e.g., trash receptacles, recycling bins, and dumpsters) that are overflowing and/or uncovered, and improper handling of trash and recycling materials during curbside collection in residential and commercial areas. Lastly, **Illegal Dumping** of large volumes of trash within a watershed or directly into a waterway is a source – typically in out-of-sight locations. This source includes trash illegally dumped or discarded at illegal encampments near or within riparian areas. Pedestrians, vehicles, and inadequate waste container management are generally considered a chronic source of trash in urbanized areas and usually occur where there are high populations of people consuming products and generating waste. In contrast, illegal dumping typically occurs sporadically and in general consists of large items (e.g., furniture and tires) compared to other source categories.

Four major trash transport pathways to water bodies are also identified. **Stormwater Conveyance Systems** can transport trash to waterways from any combination of the four source categories described above during storm events and dry weather flows. Small and floatable trash items are particularly susceptible to transport through this pathway. **Wind** can also transport trash to creeks and stormwater conveyance systems, especially when sources are located adjacent to creeks with minimal riparian vegetation and obstructions (e.g., fences). **Direct Disposal** of trash

Coyote Creek, Santa Clara County. Photograph by Larry Johmann.

### Defining Terms: Sources and Pathways

In considering the transport of contaminants into water bodies, it is important to understand the difference between a source and a pathway. "Sources" are activities leading to the release of contaminants into the environment, such as combustion of gasoline in a car engine or application of a pesticide to an agricultural crop. Sources are distinct from "pathways", which are the routes through which contaminants enter water bodies, such as stormwater (i.e., urban runoff), deposition from the atmosphere, or wastewater discharges. Pathways are sometimes misconstrued as sources.


**Figure 1**
**Trash sources and pathways to urban creeks.** Source categories include pedestrians, vehicles, waste containers, and illegal dumping. Stormwater conveyance systems, wind, direct disposal and downstream transport are the major pathways of transport to urban creeks. Urban creeks are a transport pathway to the Bay.

into creeks or along creek banks also serves as a transport mechanism. Illegal dumping and pedestrian litter are the two most prevalent trash source categories applicable to this pathway. Lastly, **Downstream Transport** of trash can occur once it enters a creek from any of the pathways described above. Depending on the physical characteristics of trash and the creek, trash may accumulate at creek sites or be transported to larger downstream water bodies (e.g., wetlands, bays, and estuaries), where the additional influence of tide, currents, and wind can affect the distribution of trash.

**Table 1**
**Six condition categories in the Rapid Trash Assessment (RTA) method used to assess the level of trash and potential risk to beneficial uses in creeks.**

| Condition Category | Description |
|---|---|
| Level of Trash | Intended to reflect a qualitative "first impression" of the site, after observing the entire length of the reach. Sites scoring in the "poor" range are those where trash is one of the first things noticeable about the water body. No trash should be obviously visible at sites that score in the "optimal" range. |
| Actual Number of Trash Items Found | Based on the tally of trash along the 100-foot stream reach. Sometimes items are broken into many pieces. |
| Threat to Aquatic Life | Focuses on identifying trash items that are persistent in the environment, including buoyant (floatable) and relatively small items that can be transported long distances and be mistaken by wildlife as food items. |
| Threat to Human Health | Identification of items dangerous to people who wade or swim in the water, and contain pollutants that could accumulate in fish in the downstream environment, such as mercury. The worst conditions have the potential for presence of dangerous bacteria or viruses, such as with medical waste, diapers, and human or pet waste. |
| Illegal Dumping and Littering | Relates to direct placement of trash items at a site, with "poor" conditions assigned to sites that appear to be dumping or littering locations based on adjacent land use practices or site accessibility. |
| Accumulation of Trash | Evaluates the level of trash that accumulates from upstream locations (i.e., downstream transport pathway). Distinguished from trash that is dumped by indications of age and transport such as faded colors, silt marks, trash wrapped around roots and signs of decay. |

## Assessing Trash Levels and Identifying Sources

Recognizing the need to establish baseline conditions of trash in San Francisco Bay Area creeks and evaluate the success of future control efforts, San Francisco Bay Regional Water Quality Control Board (Water Board) staff developed, refined, and implemented a Rapid Trash Assessment (RTA) method from 2002 through 2005 as part of its Surface Water Ambient Monitoring Program (SWAMP) (SFBRWQQCB 2007). The RTA generates site-specific scores on a scale from 0 to 120 (higher scores indicating cleaner creek sites) based on six condition categories (**Table 1**) that capture a breadth of issues associated with trash and water quality in rural and urban creeks. The SCVURPPP revised the Water Board's RTA method in 2005 to increase its resolution in identifying the most problematic sites in urban creeks within the Santa Clara Basin (SCVURPPP 2006).

To date, assessments have been conducted by the Water Board or municipal stormwater management programs at approximately 80 creek sites around the Bay. Not surprisingly, preliminary results suggest that sites lower in the watershed tend to have higher densities of trash (SFBRWQCB 2007). Likely reasons that trash accumulates in sites closer to the Bay include the increased degree of urbanization (adjacent to as well as contributing from upstream of the sites), hydrologic characteristics present (i.e., creek reaches where material deposits), and physical features (e.g., in-stream vegetation) that can snare trash as it moves downstream. Trash enters creeks throughout the year from a variety of sources and pathways. During the wet season, large amounts of trash are conveyed via stormwater from poorly kept commercial facilities, schools, bus stops, and roads (SFBRWQCB 2007). During the dry season, wind blown trash from adjacent land uses and illegal dumping on creek banks appear to be the most important trash source-pathway combinations. Homeless encampments are sources of trash at some sites (SCVURPPP 2005).

A majority of the items identified and collected during assessments were made of plastic (e.g., bottles and bags) (**Figure 2**). Materials and items made of paper/cardboard, glass, and metal were also frequently found. Plastic bottles, bags, and styrofoam pellets were the most common and abundant types of trash surveyed and removed (SFBRWQCB 2007). Research has shown that these items are long-lived and harmful to marine life (Marine Mammal Commission 1996).

## Institutional Trash Control Measures

Historically, Bay Area cities and counties have attempted to manage trash in watersheds and creeks using a variety of institutional control measures. For example, street sweeping is conducted throughout the Bay Area to remove trash from road surfaces and gutters in urbanized areas. Street sweeping is typically conducted anywhere from one to four times a month, depending on the city and land use. Over many years, cities have learned where trash is consistently deposited in streets and have adjusted street sweeping frequencies appropriately. Based on preliminary estimates, between 500,000 and 1,000,000 pounds of trash are annually removed from streets throughout the Bay Area.

Creek cleanup events are also periodically scheduled by cities and watershed groups to remove trash from water bodies. Like street sweeping, cleanup events focus on trash already in watersheds and water bodies, as opposed to preventing trash

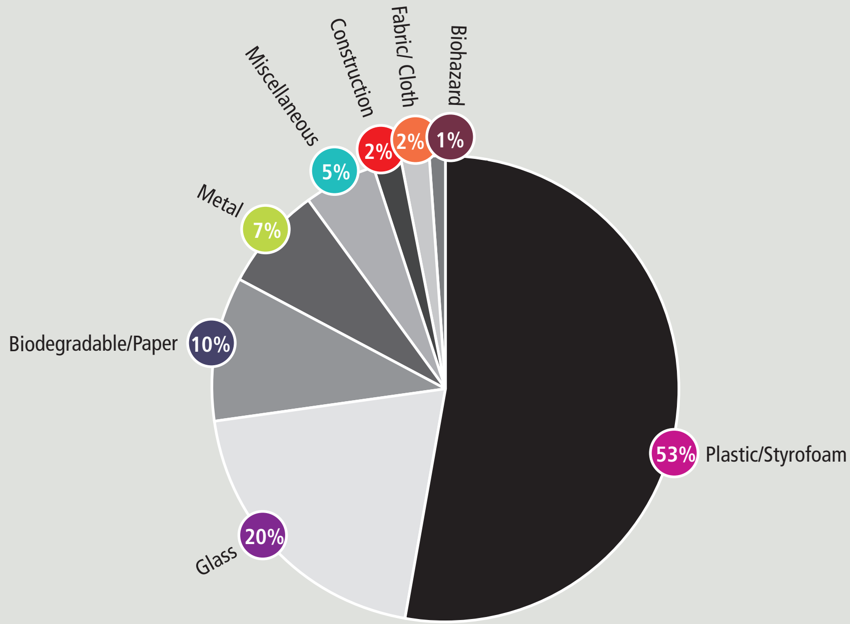



**Figure 2**
**Average percentage of trash items found during assessments in San Francisco Bay Area creeks (SFBRWQCB 2007).**

Streetsweeper and storm drain.
Photograph by Lester McKee.

Trash clean up.
Photograph by Paul Randall.

from being created. One of the primary trash removal events in California is Coastal Cleanup Day. Sponsored by California Coastal Commission, it has been conducted annually since 1985 by thousands of dedicated volunteers who pick up trash in creeks and shorelines. In 2005, over 10,000 volunteers removed roughly 173,000 lbs of trash and 30,000 lbs of recyclables from Bay Area creeks, rivers and shorelines (California Coastal Commission 2007).

To assist in preventing trash from entering creeks, public education campaigns have also been historically conducted to educate citizens about trash impacts on the environment. Who can forget "Woodsy Owl" or the "Crying Native American" as icons of watershed stewardship? The "Don't Trash California" campaign developed by CalTrans is a recent example of efforts that attempt to get the attention of citizens. The Bay Area Stormwater Management Agencies Association (BASMAA) is also focusing on trash in its multi-year regional advertising campaign through a series of TV and radio commercials called "Don't Trash Our Beautiful Watersheds".

Other institutional control measures like enhancing public ordinances focus on assessing fees to businesses that distribute or sell items frequently found in creeks. Additionally, some cities have banned the use of styrofoam and plastic products by commercial food vendors (**Sidebar next page:** Lake Merritt Trash Control Program).

## The Lake Merritt Trash Control Program

Lake Merritt has an area of 155 acres and is located immediately east of downtown Oakland. Over 60 stormwater outlets empty into Lake Merritt draining a 4,000 acre watershed. Included within this watershed is downtown Oakland, the entire City of Piedmont, numerous commercial centers, and acres of high, medium, and low density residential communities. As one can imagine, stormwater draining from this complex watershed brings a lot of trash to Lake Merritt that floats on the Lake's surface creating a visual nuisance and degrading wildlife habitat and water quality. In 1999, USEPA placed Lake Merritt on the 303(d) List for water quality impairment due to trash and dissolved oxygen.

For decades, the City of Oakland has been working to improve water quality in Lake Merritt. In 2002 the City gained access to much needed funds for capital improvement projects through the passing of Oakland Trust for Clean Water and Safe Parks (Measure DD). Using Measure DD funds, the City installed three new stormwater separator devices and will be installing several more, is piloting new trash collection technologies, and is developing a long-term Lake Merritt Trash Implementation Plan. Involvement in decision making by the community and the City staff responsible for maintaining the improvements has been a valuable component of project implementation and operation.

The City of Oakland has also been successful in passing two significant pieces of legislation that will have impacts on trash collection and reduction. The Excess Litter Fee Program, initiated in July 2005, charges fast food restaurants, liquor stores, and convenience markets a fee that is used to pay for litter pick-up. This fee seeks to make businesses that sell disposable products responsible for cleaning them up. New outreach and education and increased litter enforcement accompany this fee. In January of 2007, the Green Food Packaging Ordinance went into effect. This ordinance bans food vendors from using polystyrene foam (such as styrofoam) disposable food service ware. Additionally, the ordinance requires food vendors to change to biodegradable/compostable disposable food service ware as it becomes affordable (same or less cost than the non-biodegradable/non-compostable disposables). Both ordinances are intended to reduce the volume of trash that makes its way onto Oakland streets and ultimately into the City's precious water resources such as Lake Merritt and the Bay.


View of Lake Merritt from Lakeshore Avenue. Photograph by Linda Wanczyk.

Boaters and cormorants on Lake Merritt. Photograph by Linda Wanczyk.

# Structural Treatment Controls

Trash structural treatment controls are physical devices that are installed into stormwater catch basins, stormwater conveyance systems, on outfalls to creeks, or placed into water bodies. Stormwater treatment controls for trash typically block, separate, or catch items transported through this pathway to allow for collection and removal. Common categories of trash treatment controls include hydrodynamic separators, catch basin inserts, and outfall netting devices (**Figure 3**).

Treatment controls for trash can be applied at nearly all points in the stormwater conveyance system before it discharges to a water body. For example, screens and racks can be used at the start of the stormwater conveyance system (i.e., a storm drain) to intercept trash (**Figure 3a**). Catch basin inserts are baskets, trays, bags, or screens placed inside an inlet or at the outlet of a catch basin. Hydrodynamic (vortex) separators are in-line devices that use centrifugal forces created by the incoming flow of stormwater to collect trash (**Figure 3b**). Lastly, litter booms placed in water bodies attempt to corral trash that is already in creeks and rivers (**Figure 3c**).

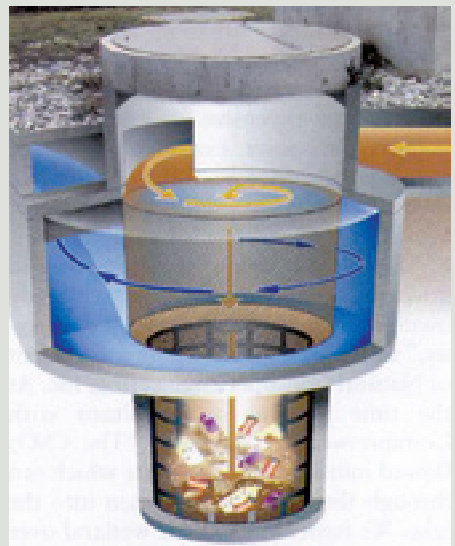
Many of these types of treatment controls have been recently piloted by Los Angeles County as part of the Total Maximum Daily Loads (TMDLs) for trash in the L.A. River and other creeks in the region. Based on design and effectiveness considerations, the L.A. Water Board can designate a trash treatment control as "full-capture" (approximately 100% removal). These are devices that trap all material retained by a fine mesh screen from all runoff generated from a 0.6 inch per hour storm, and are designed to prevent plugging or blockage of the screen (LA Water Board 2001).

### Types of Trash Controls

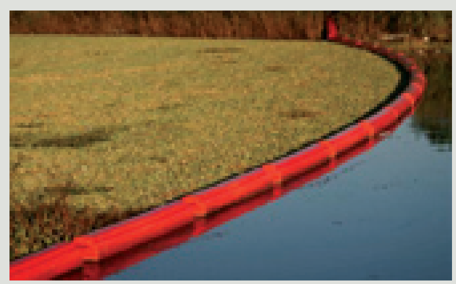
| Institutional Controls | Structural Treatment Controls |
|---|---|
| Street Sweeping | Racks & Screens |
| Waste Container Management | Hydrodynamic Separators |
| Public Education & Outreach | Litter Booms |
| Storm Drain Stenciling/Signage | Catch Basin Inserts |
| Enforcement | Netting Devices |
| Volunteer Cleanup Efforts | |
| Fees and Bans | |

a

United Stormwater Screen Cover™. Courtesy of United Stormwater, Inc.



b



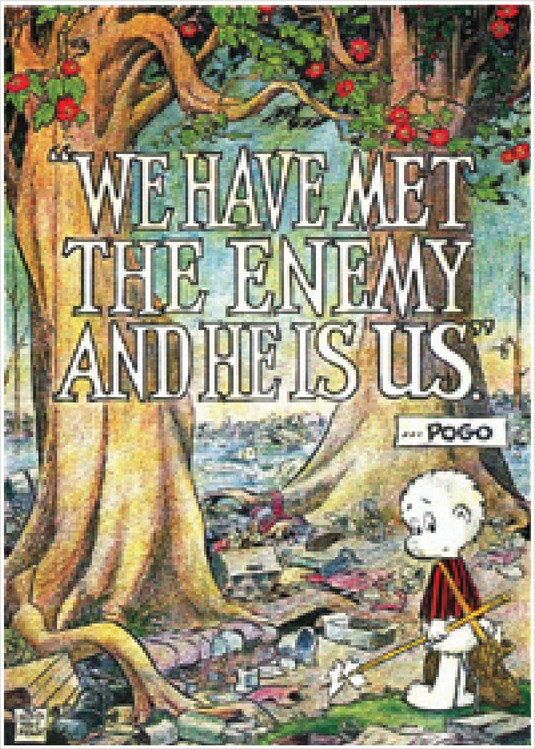
c

Tuffboom. Courtesy of Worthington Products, Inc.

**Figure 3**
Treatment controls designed to capture trash in stormwater conveyance systems. a) Screen used to block trash from entering the storm drain system; b) hydrodynamic separator that captures trash within the system; and c) litter boom which corrals trash flowing in creeks and rivers.

# Cleaning Up Creeks in the Future

Bay Area cities and counties are dedicated to identifying trash source areas and reducing trash loading to creeks and San Francisco Bay. In the last two decades, public awareness of recycling programs has increased and local agencies have revised ordinances to address continued littering and illegal dumping in creeks and watersheds. Despite management actions, trash still accumulates in Bay Area creeks. People continue to deposit trash in watersheds and on the banks of creeks without a thought to the damage it may cause the environment, fish, and wildlife. In the near future, policies like the regional stormwater NPDES permit for Bay Area municipalities will focus on developing an even better understanding of trash sources and the effectiveness of trash control measures. However, until people change their habits of carelessly disposing of consumer items and waste materials into the environment, control measures (implemented with tax dollars) will only serve as a band-aid.




Walt Kelly first used the quote "We Have Met the Enemy and He Is Us" on this poster for Earth Day in 1970.

# Copper in the Bay: Better Management Through Improved Scientific Understanding

Donald Yee, San Francisco Estuary Institute
Peter Schafer, San Jose Environmental Services Department
Tom Hall, EOA, Inc.
Richard Looker, San Francisco Bay Regional Water Quality Control Board

## Highlights

*Copper wastewater loads have decreased in the past three decades through improvements in treatment technologies and pollution prevention efforts*

*Despite loading decreases, copper concentrations have been steady since the late 1980s due to the large pool of contaminated sediment already in the Bay*

*Although concentrations are sometimes above previously established water quality criteria, much of the copper is not available for uptake or toxic*

*Attention to ongoing loads and cooperative solution-finding efforts will ensure that copper concentrations in the Bay will not increase in the future*

The Dumbarton Bridge and Dumbarton Pier. Photograph by Jay Davis.

Terms in **Blue** defined in Glossary on Inside Back Cover

# A Diminished Concern

Copper is a toxic metal that has received a great deal of attention from Bay water quality managers over the past 15 years. In the 1990s copper was a major concern, as concentrations in some areas were frequently above the water quality objectives in effect at that time. Large releases to the Bay in the past had resulted in extensive water and sediment contamination that still lingered into this era. An evaluation of the issue by the Water Board and stakeholders has led to new water quality objectives for copper in the Bay which are less stringent but still considered fully protective of aquatic life, and the removal of copper from the 303(d) List in 2002. Along with the new objectives, a program has been established to guard against future increases in concentrations in the Bay. Advances in scientific understanding of copper impacts have allowed managers to now focus greater attention on more serious threats to Bay water quality. This article provides a profile of our scientific understanding of this pollutant and the management strategy that has been developed.

# A Copper Profile

Copper has been used by humans through much of history, with functions both practical and aesthetic. Many uses result in releases of copper to the Bay, via runoff from creeks and storm drains, industrial and municipal wastewater discharges, and atmospheric deposition. Processes within the Bay resuspend and erode buried pools of previously contaminated sediments, also potentially contributing to toxic effects on Bay organisms.

Over the past several decades, substantial reductions in copper loading to the Bay have been achieved through improvements in wastewater treatment (**page 7**). Although much of the motivation for previous improvement in wastewater treatment was driven by problems with bacterial contamination and low dissolved oxygen in the Bay, side benefits included large decreases in loadings of many metals as a result of greater removal of suspended solids in the treatment process. Additional decreases have been achieved since the mid-1980s through a combination of further refinements in treatment technologies and pollution prevention efforts.

Although wastewater loadings of copper are half of what they previously were (about 40,000 lbs/year in 1987 versus 20,000 lbs/year in 2001-2003), copper concentrations in the Bay have been fairly stable over the same period. Releases from the large pool of copper-contaminated sediment already within the Bay to the water column, combined with ongoing inputs from surrounding watersheds, have resulted in no significant change in water or sediment copper concentrations in the past decade, with dissolved concentrations at some sites remaining near or above the California Toxics Rule (CTR) water quality criterion of 3.1µg/L for copper in saltwater.

### Water-Effect Ratios

A water-effect ratio (WER) is an adjustment factor allowed by USEPA for setting local water quality criteria that accounts for the effect of site-specific water characteristics on pollutant availability and toxicity to aquatic life (USEPA 2001). A WER is calculated by dividing the threshold concentration for toxicity in site water by the same result for laboratory water in side-by-side tests. This procedure is most relevant to local conditions when toxicity tests are conducted with sensitive resident species. By testing waters from various locations in a water body, the WERs derived will be representative of the typical range of conditions seen in an area. A site-specific criterion for a pollutant can then be calculated by multiplying the generic criterion by an appropriate WER.

At trace levels, copper is an essential nutrient to many organisms, with functions in various proteins and enzymes. However, at higher concentrations, copper can have acute (lethal) or chronic health impacts on many of the same organisms. The toxic effects of copper on aquatic organisms have been well documented for many species, with larval bivalves and algae among the most sensitive species. Acute toxicity thresholds of 10 µg/L or less have been found for various species, including those species used in derivation of USEPA's 1980 copper water quality criteria and subsequent updated draft copper criteria in 2003 and 2007. Over that period, with improved understanding of the mechanisms of copper toxicity in the environment, water quality criteria have evolved as well, changing from targets for total (dissolved plus particle-bound) water column concentrations, to dissolved targets, and then to dissolved targets with site-specific adjustments via water-effect ratios (WERs, **Sidebar**).

Although copper concentrations in areas of the Bay are sometimes near or over the CTR objective, not all copper is equally toxic. Copper is readily taken up by organisms (or "bioavailable") and able to cause toxic effects when it is in a freely dissolved form. However, much of the copper in the Bay is not in a freely dissolved form due to binding, or "complexation", by particles and dissolved organic compounds in Bay water. When copper is bound to these other substances, it is much less bioavailable and therefore less likely to cause toxic effects. Copper complexation in Bay water raises the concentrations of dissolved copper required to cause toxicity by 2- to 3-fold.

# Regulatory Approach

As this edition of the Pulse goes to press, the Water Board has proposed a Basin Plan Amendment that uses the information gained over the last decade on copper chemistry to modify water quality criteria for the Bay. The Amendment will include the following elements.

- A site-specific objective (SSO) of 6.9 ug/L for dissolved copper for the South Bay segment.

- A site-specific objective (SSO) of 6.0 ug/L for dissolved copper for the Central Bay, San Pablo Bay, and Suisun Bay segments.

- Defined ratios of total to dissolved copper (translators) for calculating effluent limits for wastewater sources discharging to deep-water portions of the Bay.

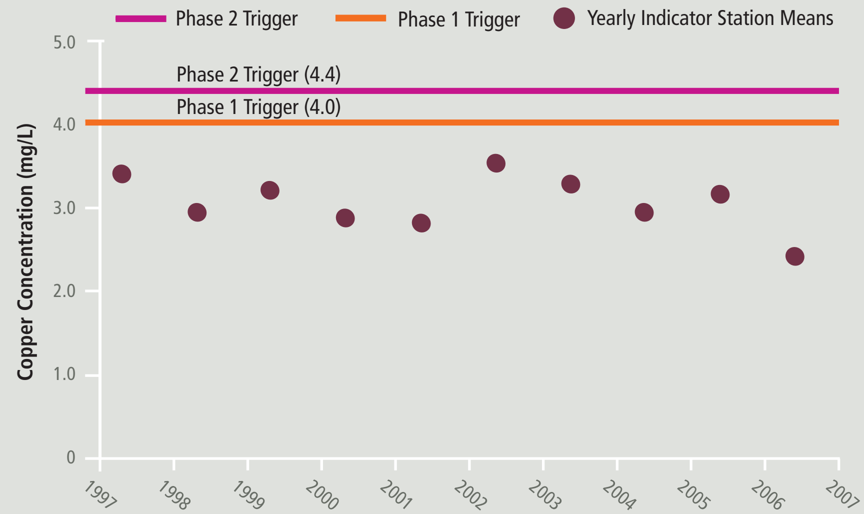
- A Bay-wide implementation strategy to ensure attainment of the SSOs. This strategy includes studies to address technical uncertainties and control measures for major sources of copper (urban runoff, wastewater treatment facilities, lagoons, and marine anti-fouling coatings).

- A water quality monitoring program designed to detect small changes in dissolved copper concentrations in the Bay that may trigger additional aggressive control measures (described below).

Although concentrations of copper in the Bay are not expected to increase in the future, the proposed copper implementation plan establishes control measures as a precaution. In order to determine that concentrations have not increased, monitoring data collected by the RMP are to be compared to specific triggers (Table 1). Copper monitoring by the City of San Jose at six stations in Lower South Bay has shown that annual average copper concentrations have consistently remained below a trigger level of 4.0 µg/L for that segment (**Figure 1**). If the trigger concentration is exceeded in any Bay segment (**Table 1**), the Water Board will investigate causes of the exceedance and consider potential control options.

## Copper Trends in the Bay

Monitoring is central to the Bay-wide management strategy to ensure compliance with the copper SSOs. Monitoring has always been crucial in establishing whether, where, when, and how contamination occurs. The City of San Jose and the Water Board first began investigating the effects of copper on Bay biota in the early 1990s. The City's study covered the Lower South Bay, and the later Water Board study included the entire Bay. These early studies, which were performed before the RMP began, examined the effects of total copper concentrations on estuarine plants and animals. The results of the Water Board study were used to modify the USEPA criterion from 2.9 to 4.9 µg/L total copper based on a comparison of the toxic effects of copper to laboratory organisms tested in Bay water versus clean laboratory water. In Bay water a large fraction of the copper is bound up in suspended sediment particles and less bioavailable. While the 4.9 µg/L SSO was not formally approved by the State Water Resources Control Board, it was used for deriving total copper effluent limits in the 1990s.




Footnote: Data from City of San Jose.

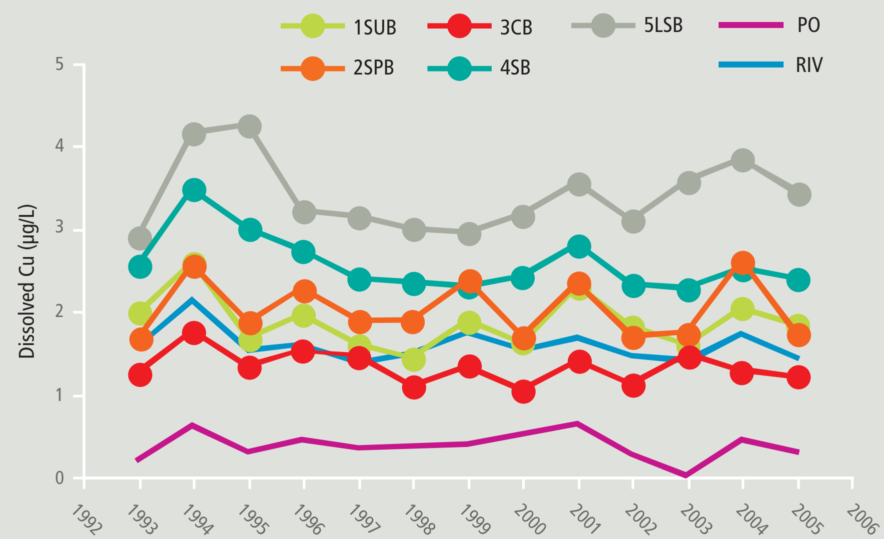
**Figure 1**
**Average Dry Weather Dissolved Copper Concentrations for Indicator Stations (in Lower South Bay).** Copper concentrations in Lower South Bay have been stable over the period monitored by the City of San Jose. Average dry season concentrations are often near the previous CTR criterion of 3.1 µg/L, but well below the new site-specific objective of 6.9 µg/L. Exceedances of trigger levels at 4.0 and 4.4 µg/L will result in additional monitoring and pollution controls to prevent continued increases.

**Table 1**
**Dissolved Copper (µg/L) Triggers.**

| Bay Segment (or portion thereof) | Trigger Level (µg/L) |
|---|---|
| Suisun Bay | 2.8 |
| San Pablo Bay | 3.0 |
| Central & Lower San Francisco Bay (north of Hayward Shoals) | 2.2 |
| Lower San Francisco Bay (south of Hayward Shoals) | 3.6 |
| South San Francisco Bay | 4.2 |

Early studies of copper in San Francisco Bay conducted prior to the RMP (Eaton 1979, Kuwabara et al. 1989) found dissolved copper concentrations ranging from 1 to 4 µg/L. In the decade between these two studies, dissolved copper concentrations remained virtually unchanged. Similarly, during the past decade there continued to be little or no change in dissolved copper concentrations in the Bay. In San Jose's monitoring of Lower South Bay, dissolved copper concentrations averaged 3.2 µg/L for the first two years (1997-1998), with the 10-year (1997-2006) average virtually identical at 3.1 µg/L (**Figure 1**). Average dissolved copper concentrations in RMP sampling have also changed little for other segments of the Bay (**Figures 2 and 3**).

Copper concentrations vary spatially in Bay waters (**Figure 4**), reflecting differences in the characteristics and relative influence of various source waters and sediments. Samples from the Golden Gate station (BC20), in the Pacific Ocean several miles offshore from the Golden Gate Bridge, and the Delta sites (BG20, BG30), upstream of the Bay, consistently show the lowest concentrations of dissolved copper. Areas away from the ocean and Delta generally show higher copper concentrations, due to the influences of past and current local watershed and wastewater loads. Given that Delta and ocean sources generally have lower concentrations of copper than those in the Bay, continued input from these cleaner sources of water and sediment will gradually decrease copper concentrations in the Bay and lead to long-term recovery.

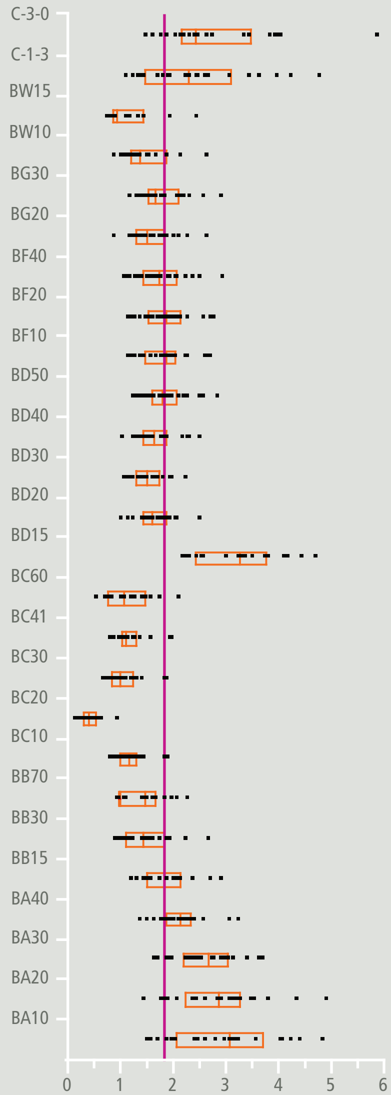

Footnote: Data from the RMP.

**Figure 2**

**San Francisco Bay Segments.** Starting in 2002, RMP largely stopped sampling from fixed stations along the spine of the Bay and began sampling randomized locations within five Bay segments. Waters from historical deeper water stations mix with those from new randomized stations, so drastic changes in dissolved pollutant concentrations are not expected.

**Figure 3**

**Annual Average Dry Season Dissolved Copper in Bay Segments, 1993-2005.** The Pacific Ocean (PO) supplies clean water to Central Bay (3CB) stations, which consistently shows the lowest dissolved copper concentrations. Delta rivers (RIV) also supply relatively clean waters to Suisun Bay (1SUB) stations. In contrast, South (4SB) and Lower South Bay (5LSB), with shallow waters, less flushing, and longer residence times show the highest concentrations.




Footnote: Data from the RMP. Bars show the median and the middle 50% of the data from each sampling station.

**Figure 4**

**Dissolved Copper (µg/L) in San Francisco Bay Waters (1993 – 2001).** BC20, in the Pacific Ocean outside the Golden Gate, consistently had the lowest dissolved copper concentrations. BD15 (Petaluma River) consistently had relatively high concentrations. Baywide, average concentrations are typically below the CTR copper objective of 3.1 µg/L, although individual measurements are often above the objective.

*Runoff from local watersheds offers some opportunities for load reduction, as specific sources and pathways can be identified and managed in watersheds, and the impacts of these management actions monitored.*

# Copper Pathways and Loads

The majority of copper enters the Bay via Delta outflow (**Figure 5**), due to the large volumes of water and sediment entering via that pathway rather than from particularly elevated concentrations in Delta water. Although control actions in the Delta watershed by the Central Valley Regional Water Quality Control Board would in principle reduce copper inputs from Delta outflow, overall those loads may prove difficult to manage and the benefits difficult to measure due to the sheer magnitude of that watershed (which includes 40% of the surface area of California) and the large volumes of cleaner water and sediment transported through the Delta.

Erosion of previously deposited contaminated sediments is estimated to be the next largest contributor of copper to the waters of the Bay. Some of the copper in sediments can become dissolved again in the water column, potentially impacting Bay biota. This is another input of copper that is not easily controlled, as much of the contaminated sediment is dispersed widely and not amenable to simple management via dredging or capping small patches of the Bay.

The third largest category, urban and non-urban runoff from local watersheds, offers some opportunities for load reduction, as specific sources and pathways can be identified and managed in watersheds, and the impacts of these management actions monitored. Changes in uses of copper (e.g., reduced application in architectural features, wood treatment, and brake pad formulations) would reduce inputs via these pathways. Atmospheric deposition loads shown in **Figure 5** only include direct deposition to Bay waters; deposition to land surfaces would appear as runoff from watersheds. Given that local watersheds draining to the Bay cover about seven times more area than the Bay itself, benefits from reduced air emissions of copper would also largely appear in reduced watershed loadings.

Other sources and pathways such as industrial and municipal wastewater are much smaller, and thus offer more limited possibilities for loading reductions and benefits on a Bay-wide scale. Nonetheless, impacts of these smaller pathways on particular Bay segments (particularly Lower South Bay) or smaller receiving waters (e.g., specific creeks or marinas) may be more pronounced than is reflected by only considering their load relative to others for the whole Bay.

## Copper Cycling and Speciation

Copper cycling among different chemical forms is important in San Francisco Bay because it plays a major role in both the fate and toxicity of this metal. Copper can exchange between the water column and particles that settle to the Bay floor, prolonging its persistence in the Bay long after discharges have decreased. The amount of copper in the top meter of sediment in the Bay is over 3000 times the dissolved copper in the water column. Even if all new sediment inputs had background levels of copper, concentrations would remain elevated in Bay waters for a long time, because only a small portion of the total sediment pool of copper can be exported to the ocean through the Golden Gate in any given year.

Although binding to sediment prolongs persistence of copper in the Bay, this also reduces its toxicity, as copper bound to particles is less bioavailable (as described above). Bioavailability is also decreased when copper is complexed in various forms. The major dissolved forms of copper are: free ions, not bound to other chemicals; weakly complexed with other inorganic ions; and moderately to strongly complexed with organic compounds. Of these forms, free copper ions and weak inorganic complexes are most bioavailable and can cause toxicity to aquatic organisms. Only a small fraction of the total copper in the water column occurs in these forms (Tetra Tech 1999).

Early copper criteria (USEPA 1985) were based on total concentrations of copper in the water column. When the RMP began to monitor in 1993, elevated total copper concentrations were detected in some areas of the Bay, raising concerns. These elevated concentrations mostly appeared to be associated with resuspension of Bay sediments (e.g., at the mouth of the Petaluma River in San Pablo Bay) or with stormwater runoff (e.g., at the mouth of Coyote Creek in Lower South Bay). In 1993, USEPA began to recommend the use of dissolved concentrations to set and measure compliance, a first step toward better addressing the bioavailable fraction of a metal in setting criteria (Prothro 1993). However, despite this change, there were still locations in the Bay where dissolved copper was often above standards.

Further improvements occurred later that decade through the development and application of local WERs. Previous copper objectives for the Bay (in the CTR) were derived from laboratory water toxicity thresholds for the blue mussel (*Mytilus edulis*). In 1996, an intensive study was conducted in Lower South Bay (**Figure 2**) by the City of San Jose to evaluate the influence of local water conditions on copper toxicity (City of San Jose 1998) and calculate appropriate WERs to develop SSOs. This was followed by further study in Bay Segments 1-4 (**Figure 2**) by the Bay Area Clean Water Agencies (BACWA). The San Jose and BACWA studies also used blue mussels in toxicity tests of both laboratory water and of Bay water. WERs were calculated from comparison of test results for various Bay water samples to results for clean laboratory water (**Figure 6**).

The consistently higher effects thresholds in Bay water indicated that dissolved copper was less bioavailable than in laboratory water. The San Jose study results were the basis for the Water Board adopting an SSO of 6.9 µg/L in Lower South Bay. The combined study results were the basis for the Water Board proposing in 2007 a Basin Plan Amendment to adopt SSOs of 6.9 µg/L for South Bay and 6.0 µg/L for Bay Segments 1-3.

These higher effects thresholds in Bay waters also corroborate results from studies indicating that most (>99%) dissolved copper in San Francisco Bay is strongly complexed, resulting in very low concentrations of the free copper ions that can cause toxicity (Buck and Bruland 2003). In that study, concentrations of free copper ions were about 100 times below the threshold at which toxic effects on phytoplankton species are first seen. However, the authors predicted that if dissolved copper concentrations in the Bay were to increase to 6.9 µg/L, free copper ion concentrations would increase to sufficient levels to cause toxicity in phytoplankton.

## Moving Forward

Copper does not appear to be as serious a threat to San Francisco Bay as previously thought, as improved scientific understanding has informed environmental management at both the national and local levels, resulting in water quality objectives better linked to the actual potential for biological impacts. Although there are no apparent long-term trends in copper concentrations in recent decades, continued monitoring with thresholds to trigger tiered investigation and mitigation will be essential to ensure that the gains made to date are not lost through inattention.

In addition to these reactive measures, proactive measures are underway to ensure that water quality is maintained or continues to improve even before direct evidence of degradation is acquired. Many strategies for copper pollution prevention efforts are listed at the Santa Clara Valley Urban Runoff Pollution Prevention Program Copper Sources and Management Strategies Clearinghouse (www.scvurppp-w2k.com/cu_clearinghouse_web/cu_source.htm). A few of many examples include: adjusting water supply characteristics and plumbing design and installation practices to minimize pipe corrosion (BACWA 2003); reducing architectural uses of copper

(City of Palo Alto 2003); best management practices and wastewater control from vehicle washing (CASQA 2003).

One of the growing concerns in the last decade is the increasing use of copper in vehicle brake pad formulations, after a preliminary study suggested that half the copper in urban runoff could originate from this source. The Brake Pad Partnership (BPP) (www.suscon.org/brakepad) was formed in 1996 as a collaborative effort to bring together government regulators, brake pad manufacturers, stormwater management agencies, and environmentalists. Rather than an antagonistic approach with competing experts battling in the courts and media, the members of the BPP are concentrating on combining the best available information to assess the situation and find appropriate solutions. A BPP investigation is ongoing, using Castro Valley Creek watershed as a case study, for modeling brake pad copper emissions, transport, and fate. Reports on brake pad and non-brake pad copper sources in the watershed, brake pad wear debris characteristics, atmospheric deposition monitoring, air transport modeling, and stormwater quality monitoring are completed, with completion of the remaining project elements (watershed and Bay transport modeling) anticipated in 2007. Such proactive approaches, identifying potential problems and developing information to address data gaps, present opportunities for parties to find constructive solutions in a collaborative manner.

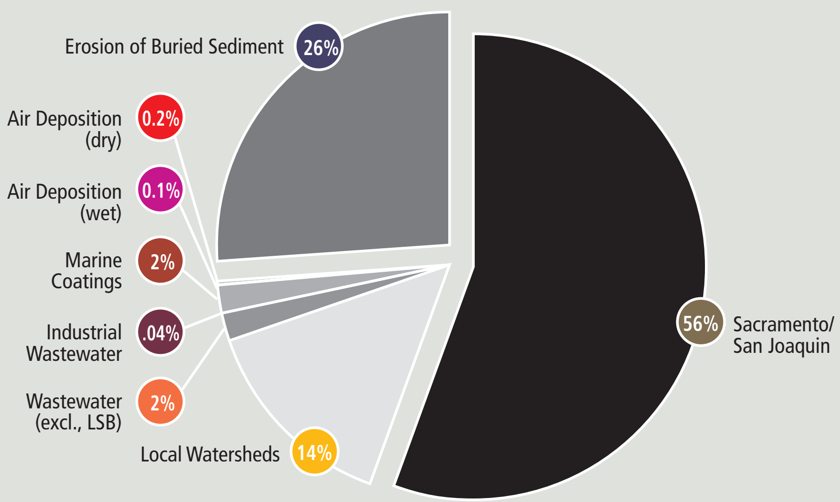



**Figure 5**
**Copper Inputs to San Francisco Bay Waters, Percentage of 1300 kg/day Total Load.** Mass loads of copper to the Bay are dominated by inputs from the Delta despite concentrations that are typically below Bay averages, simply due to the large flows of water and sediment entering via that pathway. Local watersheds contribute a smaller but substantial portion, with minor contributions from various other sources. About a quarter of total estimated inputs are needed from resuspension of Bay sediments to account for water column concentrations of copper observed (CEP 2004a, 2004b, Tsai et al. 2001, TDC 2004, SFBRWQCB 2005).


Footnote: See Figure 2 for delineation of Bay segments.

**Figure 6**
**Laboratory and San Francisco Bay Water *Mytilus edulis* EC50 Values for Bay Regions.** Toxicity test EC50s (concentration at which toxic effects are observed in 50% of organisms) are higher for all Bay region waters compared to laboratory controls. San Pablo and South Bay (Regions 2, 4, and 5), with greater local tributary influences, had higher dissolved copper concentrations (Figure 4), but also showed lower sensitivity to copper toxicity (higher EC50s).

# References


## Management Update

### Krieger

Breslaw, J. 1972a. Industrial Waste Discharges in the San Francisco Bay Region. Lawrence Berkeley Laboratory–1001 Preprint.

Breslaw, J. 1972b. Industrial Waste Discharges in the San Francisco Bay Region. Lawrence Berkeley Laboratory – 1001 Preprint. Reprinted in Breslaw, Jon A. 1974. Sources and trends in waste loadings to the San Francisco Bay region. Water Resour. Res., 10(6):1085–1089.

California Water Boards. 2006. Clean Water Act Section 305b Report 2006, Water Quality Assessment of the Condition of California Coastal Waters and Wadeable Streams October 2006. Posted at: http://www.swrcb.ca.gov/swamp/docs/factsheets/305breport2006.pdf

Hyde, G.C., H.F Gray, A.M. Rawn. 1941. East Bay Cities Sewage Disposal Survey, Report Upon the Collection, Treatment and Disposal of Sewage and Industrial Wastes of the East Bay Cities, California. The Board of Consulting Engineers. Cited in University of California, Berkeley, Strawberry Creek Water Quality–2006 Status Report. 2006. Office of Environment, Health & Safety.

Kaiser Engineers. 1969. San Francisco Bay Delta Water Quality Control Program–Final Report to the State of California.

Lam, J. 2007. Spreadsheet: 1986-2005 Metal Loading data from EBMUD San Jose CCSD and SF Southeast August 9–2006.xls.

Luoma S.N, J.E. Cloern. 1982. The Impact of Waste-Water Discharge on Biological Communities in San Francisco Bay. In San Francisco Bay: Use and Protection. Edited by W.J. Kockelman, T.J. Conomos, and A.E. Leviton. The data referenced are: California Regional Water Quality Control Board. 1977. Report on bacteriological survey in San Francisco Bay. 28 February-?, March, 1977. In-house publication.

Scott, M. 1963. The Future of San Francisco Bay. Institute of Governmental Studies, University of California, Berkeley.

SFBRWQCB. 1975. Water Quality Control Plan Report. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

SFBRWQCB. 1987. Municipal Division Program Activities Report, FY 1985-86. Richard Condit, Editor. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

SFBRWQCB. 2007. Executive Officer's Report–May (Lila Tang). San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

SWRCB. 1971. Clean Water for San Francisco Bay, A Report to the Legislature. California State Water Resources Control Board, Sacramento, CA.

SWRCB. 1978. A Biennial Report. California State Water Resources Control Board, Sacramento, CA.

United States. 1987. Contamination of the San Francisco Bay: oversight hearing before the Subcommittee on Water and Power Resources of the Committee on Interior and Insular Affairs, House of Representatives, Ninety-ninth Congress, second session, on contamination of the San Francisco Bay, hearing held in San Francisco, CA, August 4, 1986. Washington [D.C.]: U.S. G.P.O.

### DeShields

Cutter GA, Cutter LS. 2004. Selenium biogeochemistry in the San Francisco Bay estuary: changes in water column behavior. Estuarine Coastal Shelf Science 61:463-476.

Gunther, A.J., J.A. Davis, and D.J.H. Phillips. 1987. An Assessment of the Loading of Toxic Contaminants to the San Francisco Bay-Delta. San Francisco Estuary Institute, Oakland, CA.

## Water Quality Trends at a Glance

Fairey, R., K. Taberski, S. Lamerdin, E. Johnson, R.P. Clark, J.W. Downing, J. Newman and M. Petreas. 1997. Organochlorines and other environmental contaminants in muscle tissues of sportfish collected from San Francisco Bay. Marine Pollution Bulletin 34(12): 1058–1071.

## Feature Articles

### Davis

Cloern, J.E., T.S. Schraga, C.B. Lopez, and R. Labiosa. 2003. Lessons from Monitoring Water Quality in San Francisco Bay. Pages 15 – 20 in: SFEI. 2003. The Pulse of the Estuary: Monitoring and Managing Contamination in the San Francisco Estuary. SFEI Contribution 74. San Francisco Estuary Institute, Oakland, CA.

Hoenicke, R. 2005. Adapting the Regional Monitoring Program to Answer the Important Questions. Pages 4 – 11 in: SFEI. 2005. The Pulse of the Estuary: Monitoring and Managing Water Quality in the San Francisco Estuary. SFEI Contribution 411. San Francisco Estuary Institute, Oakland, CA.

Sanudo-Wilhelmy, S.A., Tovar-Sanchez, A., Fisher, N.S., Flegal, A.R. 2004. Examining toxic metals in US estuaries. Environ. Sci. Technol. 38, 34A–40A.

SFBRWQCB. 2006. Final 2006 303(d) List, San Francisco Bay Region. http://www.waterboards.ca.gov/tmdl/docs/303dlists2006/final/r2_final303dlist.pdf

van Geen, A. and S.N. Luoma. 1999. The impact of human activities on sediments of San Francisco Bay, California: an overview. Marine Chemistry 64 1999 1–6.

### Sommers

California Coastal Commission. 2007. Recap of the 21st Annual California Coastal Cleanup Day. http://www.coastal.ca.gov/publiced/ccd/recap2005.pdf.

LA Water Board. 2001. Trash Total Maximum Daily Loads for the Ballona Creek and Wetland. California Regional Water Quality Control Board - Los Angeles Region September 19. http://www.waterboards.ca.gov/losangeles/html/meetings/tmdl/ballona_creek/01_0919_bc_Ballona%20Creek%20Trash%20TMDL.pdf.

Laist, D. W. and M. Liffmann. 2000. Impacts of marine debris: research and management needs. Issue papers of the International Marine Debris Conference, Aug. 6-11, 2000. Honolulu, HI, pp. 16-29.

Marine Mammal Commission. 1996. Marine Mammal Commission Annual Report to Congress. "Effects of Pollution on Marine Mammals." Bethesda, MD. 247 p.

SCVURPPP. 2005. Technical Memorandum - Trash Problem Area Evaluation Results for FY 04-05. August 19. Santa Clara Valley Urban Runoff Pollution Prevention Program. http://www.scvurppp-w2k.com/project_reports_fy0405/274_Trash_Problem_Area_Results.pdf.


Forster's Tern at Arrowhead Marsh. Photograph by Linda Wanczyk.

SCVURPPP. 2006. Technical Memorandum - Development of Urban Rapid Trash Assessment Protocol. March 13. Santa Clara Valley Urban Runoff Pollution Prevention Program. http://www.scvurppp-w2k.com/pdfs/0506/RTA_Draft_Memo_031306-ALL.pdf.

SFBRWQCB. 2007. A Rapid Trash Assessment Method Applied to Waters of the San Francisco Bay Region: Trash Assessment in Streams - Final Technical Report. San Francisco Bay Regional Water Quality Control Board, Oakland, CA. www.swrcb.ca.gov/rwqcb2/Stormwater/swamp/R2%20SWAMP%20Trash%20Report%20final%20April07.pdf.

**Yee**

BACWA. 2003. Good Plumbing Practices Protect San Francisco Bay A Fact Sheet for Installers / Plumbers. Bay Area Clean Water Agencies. http://www.scvurppp-w2k.com/cu_clearinghouse_web/cu_pipe/01-Good_Plumbing_Practices_Protect.pdf

Buck, K.N. and Bruland, K.W. 2003. Copper Speciation in San Francisco Bay. Draft Report for the State Water Resources Control Board.

CASQA. 2003. Vehicle and Equipment Cleaning. California Stormwater Quality Association. http://www.cabmphandbooks.com/Documents/Industrial/SC-21.pdf

CEP. 2004a. North of Dumbarton Bridge Copper & Nickel Conceptual Model and Impairment Assessment Report. EOA/LWA. Clean Estuary Partnership. December 2004.

CEP. 2004b. North of Dumbarton Bridge Copper & Nickel Site-Specific Objectives State Implementation Policy Justification Report. EOA/LWA. Clean Estuary Partnership. December 2004City of San Jose. 1998. Development of a Site-Specific Water Quality Criterion for Copper in South San Francisco Bay.

City of Palo Alto. 2003. Municipal Code Section 16.09.160(b)). http://www.city.palo-alto.ca.us/government/municipalcode.html

City of San Jose. 1998. Development of a Site-Specific Water Quality Criterion for Copper in South San Francisco Bay.

Eaton, A (1979). Observations on the Geochemistry of Soluble Copper, Iron, Nickel , and Zinc in the San Francisco Bay Estuary. Environmental Science and Technology Vol. 13, No. 4, p 425-432.

Kuwabara, JS; Chang, CCY; Cloern, JE; Fries, TL; Davis, JA (1989). Trace Metal Associations in the Water Column of South San Francisco Bay, California. Estuarine Coastal and Shelf Science ECSSD3, Vol. 28, No. 3, p 307-325.

Prothro, M.G. 1993. Memorandum titled "Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria" to Water Management Division Directors, Environmental Services Division Directors, Regions I-X, October 1, 1993, from Martha G. Prothro, Acting Assistant Administrator for Water, U.S. Environmental Protection Agency, Washington, D.C.

SFBRWQCB. 2005. Copper And Nickel Concentrations In San Francisco Bay Sediment Cores, prepared by R. Looker, April 27, 2005. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

Tetra Tech Inc., 1999. Task 1. Conceptual model report for copper and nickel in lower South San Francisco Bay, Lafayette, CA, 156pp.

TDC Environmental, 2004. (TDC) Copper Sources in Urban Runoff and Shoreline Activities. Prepared for the Clean Estuary Partnership. November 2004.

Tsai et al. 2001. San Francisco Bay Atmospheric Deposition Pilot Study, Part 2: Trace Metals. SFEI Contribution 73. pp. 8, 47-53.

USEPA, 1985. Ambient Water Quality Criteria for Copper – 1984. United States Environmental Protection Agency Office of Water Regulations and Standards. Washington DC. EPA 440/5-84-031. January 1985.

USEPA, 2001. Streamlined Water-Effect Ratio Procedure for Discharges of Copper. United States Environmental Protection Agency Office of Water. EPA-822-R-01-005. March 2001

# Credits and Acknowledgments

**Editors**
Jay Davis, Michael Connor

**Contributing Authors**
Jay Davis

**Information Compilation**
Katie Harrold, Meg Sedlak, Jennifer Hunt, Sarah Lowe, Lester McKee, John Ross, Josh Collins

**RMP Data Management**
Sarah Lowe, Cristina Grosso, John Ross, Amy Franz, Predrag Stevanovic, Don Yee

**Mapping and Graphics**
John Oram, Eric Zhang, Shira Bezalel

**Art Direction & Design**
Linda Wanczyk

**Information Graphics**
Joanne Cabling

**Printing**
Alonzo Printing, www.alonzoprinting.com

**The following reviewers helped improve this document by providing comments on draft versions:**

Sheila Tucker
Kelly Moran
Jim Kuwabara
Rainer Hoenicke
Tom Hall
Karen Taberski
Chuck Weir
Dave Tucker
Dan Tafolla
Katie Harrold
Meg Sedlak
Trish Mulvey
Geoff Brosseau
Andy Cohen
Lester McKee
Nicole David

The Paper
Reincarnation™ is the most environmentally friendly matte coated paper stock in the world and is made from 100% recycled content, 50% Post-Consumer Waste and processed entirely without chlorine.

The Ink
Soy based ink made from soybeans. Soy ink is a helpful component in paper recycling. It helps in this process because the soy ink can be removed more easily than regular ink during the de-inking process of recycling. This allows the recycled paper to have less damage to its paper fibers and have a brighter appearance. The waste that is left from the soy ink during the de-inking process is not hazardous and it can be treated easily.

San Francisco Estuary Institute
and the
Regional Monitoring Program
for Water Quality in the San Francisco Estuary

7770 Pardee Lane, 2nd Floor, Oakland, CA 94621
p: 510-746-SFEI (7334), f: 510-746-7300, www.sfei.org

# Glossary

Seal lions at Fisherman's Wharf. Photograph by Jay Davis.

**303(d) List**
Official list of water bodies that do not meet water quality standards, required by Section 303(d) of the Clean Water Act.

**Acute toxicity tests**
Toxicity tests that measure mortality in a relatively short exposure period.

**Atmospheric deposition**
The transfer of pollutants from the atmosphere to the water or land surface.

**Basin Plan**
Water Quality Control Plan for the San Francisco Bay Basin The Water Board's master water quality control planning document for the Bay. It designates beneficial uses and water quality objectives, and includes programs of implementation to achieve water quality objectives.

**Beneficial uses**
Specific benefits derived from a water body that water quality managers strive to protect. Some important uses of the Bay are fishing, habitat for aquatic life, contact and non-contact water recreation, and shellfish harvesting.

**Best practicable technology**
A level of treatment based on available technology established by USEPA under the Clean Water Act for each class of industry emitting pollution.

**Bioaccumulation**
The accumulation of pollutants by living organisms.

**Bioaccumulative**
Describes pollutants with a tendency to accumulate in living organisms.

**Biosolids**
Nutrient-rich organic materials resulting from the treatment of domestic sewage in a treatment facility.

**BOD**
**Biochemical Oxygen Demand**
A measure of the amount of organic matter in water that consumes and depletes dissolved oxygen.

**California Toxics Rule**
Rule promulgated by USEPA in 2000 that made federal water quality criteria legally applicable to California waters (i.e., equivalent to water quality objectives).

**Capping**
Covering contaminated sediment with cleaner sediment in a manner that keeps the contaminants out of circulation.

**Central Bay**
See Figure 2, page 82.

**Chlordane**
A persistent, chlorine-based organic chemical widely used as an insecticide until it was banned in 1988.

**Chronic toxicity tests**
Toxicity tests that measure sublethal responses such as growth or reproduction in a relatively long exposure period.

**Coliform bacteria**
Bacteria found in the intestinal tract of humans and animals. Their presence in water indicates fecal pollution and potentially adverse contamination by pathogens.

**Conservative**
A substance that does not become degraded in the Bay.

**Copper**
A heavy metal used in many products, including brake pads and pesticides, that is highly toxic to aquatic life, especially bivalves and algae.

**Cyanide**
General term for a group of compounds containing carbon and nitrogen, some of which are toxic. Small amounts of cyanide are formed in municipal wastewater treatment plants as a by-product of disinfection processes, such as chlorination.

**DDT**
A ubiquitous, persistent, chlorine-based organic chemical widely used as an insecticide until it was banned in 1972.

**Delta outflow**
Water and associated sediment and pollutants that flow from the Sacramento-San Joaquin Delta into the Bay.

**Diazinon**
An organophosphate insecticide commonly used in agriculture and residential pest control through the 1990s. Residential use was banned in 2004.

**Dieldrin**
A persistent, chlorine-based organic chemical widely used as an insecticide until it was banned in 1988.

**Dilution credit**
Mechanism by which dischargers to waters with greater dilution are granted more lenient effluent limits.

**Dioxins**
Highly toxic, persistent organic chemicals that are primarily by-products of combustion and accumulate in food chains.

**Dissolved concentrations in water**
The fraction of a pollutant concentration that is not associated with sediment particles suspended in a water sample.

**DO**
**Dissolved oxygen**
Oxygen that is dissolved in water. DO is vital to aquatic organisms.

**Dredging windows**
Limited periods of time in which dredging and disposal of dredged material are allowed because impacts on aquatic species such as migratory fish are unlikely.

**Emerging pollutants**
Pollutants where water quality objectives are not in place, but limited information available suggests possible ecological or human health risks.

**Exotic species**
Non-native aquatic species introduced to the Bay.

**Impairment**
Interference with a beneficial use.

**Implementation**
Carrying out plans to improve water quality and restore beneficial uses.

**Legacy pesticides**
**Includes DDT, Dieldrin, and Chlordane**
Persistent insecticides widely used in the 1950s and 1960s, banned in the 1970s and 1980s, but still accumulate in the food chain.

**Legacy pollutants**
Persistent pollutants that entered the Bay as a result of historical activities no longer practiced.

**Loading**
The release or transport of a mass of pollutant into the Bay.

**Lower South Bay**
The portion of the Bay south of the Dumbarton Bridge. See Figure 2, page 82.

**Mercury**
A heavy metal that accumulates in the food chain and is highly toxic.

**Methylmercury**
The problematic form of mercury that comprises only about 1% of total mercury in aquatic ecosystems, but accumulates in the food chain and is highly toxic.

**Narrative water quality objective**
A water quality objective that does not specify numeric limits.

**Nickel**
A heavy metal used in many products that is moderately toxic to aquatic life.

**NPDES Program**
National Pollutant Discharge Elimination System - A provision of the Clean Water Act which prohibits discharge of pollutants into waters of the United States unless a special permit is issued by USEPA, a state, or tribal government.

**Nonpoint source**
Diffuse pollution sources without a single point of origin. The pollutants are generally carried off the land by storm water.

**Nonurban runoff**
Runoff from nonurban lands, such as agricultural lands, pastures, and open space.

**North Bay**
See Figure 2, Segments 1 & 2, page 82.

**Nutrients**
Nitrogen, phosphorus, and other elements that stimulate growth of algae.

**Organophosphates**
A class of insecticides that contain phosphorus. Diazinon and chlorpyrifos are prominent examples.

**PAHs**
**Polycyclic Aromatic Hydrocarbons**
Organic chemicals that are found in petroleum and are formed in petroleum combustion, and are toxic to aquatic organisms.

**Pathogen**
Bacteria or viruses that can cause illness.

**Pathways**
The routes through which contaminants enter the Bay, such as urban runoff, streams and rivers, deposition from the atmosphere, or wastewater discharge. Pathways are sometimes misconstrued as sources.

**PBDEs**
Polybrominated diphenyl ethers
A class of flame retardant chemicals that contain bromine and accumulate in aquatic food chains.

**PCBs**
Polychlorinated biphenyls
Persistent, toxic organic chemicals that were widely used by electrical utilities and industry, banned in 1979, but still accumulate in the food chain today.

**Petroleum hydrocarbons**
Organic chemicals, including PAHs and others, that are found in petroleum and are toxic to aquatic organisms.

**Pollution prevention**
Reducing or eliminating pollutants at the source by modifying production processes, the use of non-toxic or less-toxic substances, conservation, and re-use of materials.

**POTW**
**Publicly-owned treatment works**
A facility that treats sewage and wastewater from homes, businesses, and industry prior to discharge of the water into the Bay or other water body.

**ppb**
**parts per billion**
A unit describing concentrations. For example, 1 ppb is equivalent to 1 milligram of pollutant in 1000 kilograms of sediment.

**ppm**
**parts per million**
A unit describing concentrations. For example, 1 ppm is equivalent to 1 milligram of pollutant in 1 kilogram of sediment.

**Pretreatment**
Treatment to reduce the level of pollutants discharged by industry and other non-domestic wastewater sources into municipal sewer systems.

**Primary treatment**
The first stage of the wastewater treatment process where mechanical methods, such as filters and scrapers, are used to remove pollutants.

**Pyrethroids**
Insecticides that are currently heavily used and are highly toxic to fish and aquatic invertebrates.

**San Pablo Bay**
See Figure 2, page 82.

**Secondary treatment**
A wastewater treatment process involving the biological process of reducing organic matter through bacterial metabolism.

**Sediment quality objectives**
Guidelines for the protection of sediment quality, similar to water quality objectives.

**Sediment Toxicity**
An index of sediment pollution derived from exposure of test organisms to sediment from the Bay.

**Selenium**
An element that enters the Bay from agricultural runoff and wastewater effluent, accumulates in the food chain, and is toxic to aquatic life.

**Silver**
A heavy metal formerly used in photo processing that is highly toxic to aquatic life.

**Site-specific objectives**
Water quality objectives developed for a specific water body that are adjusted due to local water quality factors that affect the risks posed by a pollutant.

**Sources**
Activities leading to the release of pollutants into the environment, such as combustion of gasoline in a car engine or application of a pesticide to an agricultural crop.

**South Bay**
See Figure 2, page 82.

**Suisun Bay**
See Figure 2, page 82.

**Suspended solids**
Particles of solid material suspended in water.

**Technology-based effluent limit**
Effluent limits based on application of the best available treatment technology.

**Tertiary**
A third stage of wastewater treatment that removes nutrients or other pollutants that resist conventional treatment practices.

**TMDL**
**Total maximum daily load**
A cleanup plan called for by the Clean Water Act, based on determining the maximum load that an aquatic ecosystem can receive without adverse impacts.

**Total concentrations in water**
The sum of the dissolved fraction and the particle-associated fraction of pollutants in a water sample.

**Total mercury**
The overall sum of all forms of mercury.

**Toxicity**
The observation of a significant toxic response in a toxicity test.

**Toxicity test**
A laboratory procedure in which test organisms are exposed to pollutants under controlled conditions.

**TSS**
**Total suspended solids**
A measure of the amount of sediment particles in water.

**Ultra-clean techniques**
Chemical analysis techniques that take extreme precautions to avoid sample contamination. Necessary for measuring minute amounts of pollutants in environmental samples.

**Urban runoff**
Runoff from urban areas driven primarily by rainstorms but also by irrigation.

**Water Board**
The San Francisco Bay Regional Water Quality Control Board. The agency with primary responsibility for managing water quality in the Bay.

**Water column**
The volume of water between the surface of the Bay and the bottom sediment of the Bay.

**Water quality based effluent limit**
Effluent limits applied to discharges when application of technology-based limitations would still cause violations of water quality standards.

**Water quality criteria**
A numerical value for a pollutant set by the USEPA to protect aquatic life, wildlife, or human health. Water quality criteria are not binding until adopted as water quality objectives by the state via a regulatory action.

**Water quality objectives**
Legally enforceable numerical or narrative guidelines, usually based on federal water quality criteria, established to protect beneficial uses of a water body.

**Water quality standards**
Collectively the beneficial uses of a water body, the water quality objectives (which can be numerical or narrative) established to protect the beneficial uses, and the antidegradation policy.

printed on recycled paper