行政院所屬各機關因公出國人員出國報告書

（出國類別： 考 察 ）

考察美國海域水質監測技術
出國報告書

服務機關： 行政院環境保護署

出國人 職 稱： 技 士 分析師

姓 名： 陳妙玲 洪啟富

出國地點： 美國

出國期間： 民國九十二年十二月二日至九十二年十二月十一日

報告日期： 民國九十三年三月十日

行政院研考會/省（市）研考會編號欄
G14/C09204036

中美環保技術合作計畫

考察美國海域水質監測技術

目錄

第一章 前言

1. 緣起

台灣地區四面環海，本署每年均定期執行海域環境水質監測，自八十九年起為提供民眾夏季休憩海域戲水參考，於每年六至九月增加二週檢測一次的休憩海域水質監測。監測資料除提供發布外，相關資料並整理建檔，建立環境水質背景資訊。

監資處自九十一年起接辦環境水質監測業務，為提昇本署海域水質監測及分析技術，增進同仁海域水質監測知能，並借重國外近岸海域水質監測技術，作為本署未來海域水質監測發展應用。藉由本次出國考察，對於近岸海域水質監測及資料分析技術等將有助益，期望借重外國經驗進行我國水質監測及資料處理借鏡。

2. 目的

藉由參與本次出國考察計畫，觀摩海域水質監測體系、資料蒐集及分析技術，蒐集國際海域水質即時監測相關資訊，作為本署環境海域水質監測相關業務推動參考，並可增進我國與美國環保合作關係。

3. 考察行程

本次出國參訪自九十二年十二月二日至十二月十一日，出國期間參訪單位包括 **US EPA Region 9** 美國環保署第九區、舊金山區域水質管理局 San Francisco Regional Water Quality Control Board

（SFBRWQCB）、舊金山灣管理委員會 San Francisco Estuary Institute（SFEI）及 Mt. View Sanitary District（Mt. VSD）等單位，其中 San Francisco Estuary Institute 係是由各領域專家學者組成的非政府組織之管理委員會，Mt. View Sanitary District 是民間機構，對於環境水質監測都有相當豐富的經驗。以下是本次受訪單位及人員簡要說明：

（1）**US** Environmental Protection Agency **Region 9** 美國環保署第九區

Janet Y. Hashimoto 環境監測部門主管

Eric Wilson 監測資料庫規劃、設計

（2）舊金山區域水質源管理局 San Francisco Regional Water Quality Control Board（SFBRWQCB）

Karen M. Taberski 水資源管理

Revital Katznelson, Ph.D., 水質監測規劃設計及執行

（3）舊金山灣區管理委員會 San Francisco Estuary Institute （SFEI）

Mike Connor, Ph.D. Executive Director 監測計畫主持人

Jay Davis, Ph.D. 監測計畫總負責

Don Yee 水質監測資料彙整、資料庫管理。

（4）Mt. View Sanitary District（MVSD）

Dick Bogaert Wetlands Biologist/Analyst、

David R. Contreras District Manager、

Teng-Chung Wu. PH.D, P.E. 吳登中博士，技術服務部門主管

表一 參訪行程

日期	地點	工作內容
九十二年十二月二日(星期二)	台北 到 舊金山	起程
九十二年十二月三日(星期三)	舊金山	抵達美國，資料蒐集。
九十二年十二月四日(星期四)	舊金山	參訪美國環保署監測體系及分析技術。(USEPA)
九十二年十二月五日(星期五)	舊金山	參訪美國環保署監測數據分析技術。(USEPA)
九十二年十二月六日(星期六)	舊金山	收集自動監測資料。
九十二年十二月七日(星期日)	舊金山	收集自動監測資料。
九十二年十二月八日(星期一)	舊金山	參訪美國環保署海域水質監測及資料分析技術。
九十二年十二月九日(星期二)	舊金山	參訪美國環保署海域水質檢測技術。
九十二年十二月十日(星期三)	舊金山	搭機
九十二年十二月十一日(星期四)	舊金山 到 台北	返國。

第二章 環保署 Region 9 考察紀要

美國環保署第九區辦公室所執行之環境水質監測，包括美國西南區域加州、內華達及亞利桑那地區。環保署環境水質監測包括河川、水庫、海域（河口）及休憩海域等水質監測，主要工作內容為監測策略規劃、監測資料庫維護及資料發布等。水質監測工作分由舊金山區域水資源管理局（SFBRWQCB）、舊金山灣區管理委員會（SFEI）、美國地理學會 U.S. Geological Survey（USGS）及以民間企業組成的志工進行，藉由網際網路將相關監測資料依環保署已規劃之格式回傳監測庫，所有監測數據均包含相關數據品保、品管資訊，藉由水質資料管理維護系統（STORET）進行監測數據管理。

在河川水質監測方面，每年由加州、內華達及亞利桑那地區河川收集十餘個水樣進行檢測，監測結果以受損害河川長度（extent of river impairments）進行評析，河川監測資料以監測長度（assessed）及受損害（impaired）表示。

在沿岸（coastal）水質監測方面，1999 年進行小型河口（estuaries）監測，2000 年監測舊金山灣等大型河口，2001 年進行溼地監測，2003 年開始進行遠洋（offshore）監測，每年有不同的監測目標。監測內容包括水質重金屬、生物毒性及底質（sediment）等，水質監測結果以良（good）、一般（fair）、劣（poor）三個等級表示。

圖一　環保署門口留影紀念（一）

因為911事件影響，環保署規定辦公大樓內不得攝影。
所有人員只好在人來人往的大樓前合影留念。
照片中央為美方接待人員 Janet Y. Hashimoto，
右二是管理監測資料庫的資訊人員 Eric Wilson。
最右邊是已經在舊金山研習半年的經濟部永續發展小組林華宇，協助我們此行在美期間各項事務。

圖二　環保署門口留影紀念（二）

右邊是任職美國環保署的華人 Jessica Kao。

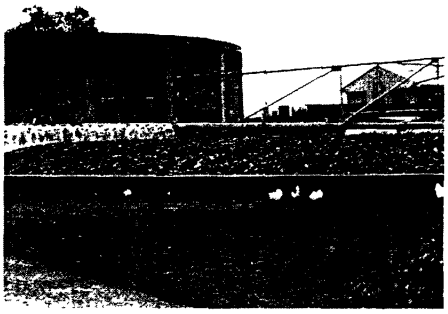
第三章 Mt. View Sanitary District 考察紀要

Mt. View Sanitary District（MVSD）是一家民間企業公司，位於舊金山附近。該公司設有二級污水處理設備，除依規定定期進行水質監測外，因地利之便亦投入溼地保護及生態環境教育等工作。

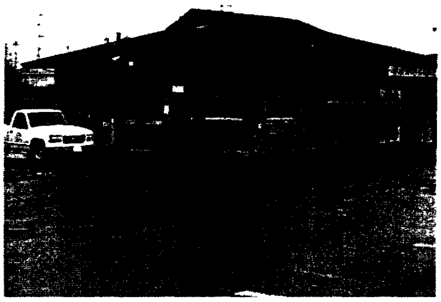
MVSD 水質監測係屬污水處理廠水質處理排放之放流水監測，監測項目包括 pH、BOD、COD、大腸桿菌群 *Coliforms* 等，為避免放流水影響環境水質，放流水先經魚毒試驗，確定水質正常穩定後再放流於溼地，進行溼地復育。相關監測資料依環保署已規劃之格式，藉由網際網路回傳監測庫資料。

圖三　Mt. View Sanitary District 門口留影紀念

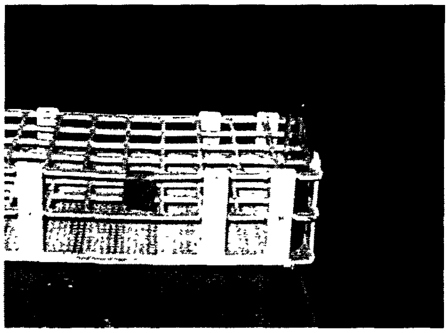
照片中央為 Dick Bogaert ，右二是 Teng-Chung Wu.
吳登中博士 PH. D, 技術服務部門主管。



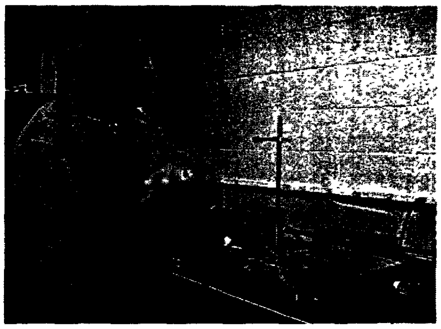
污水處理設備



水質監控實驗室



大腸桿菌群檢測之確認試驗

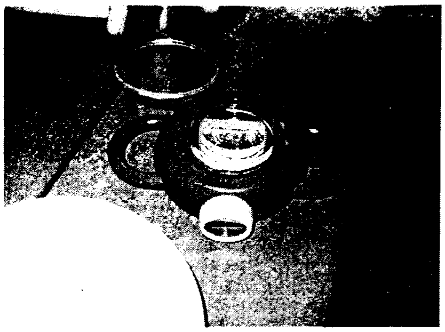


接待人員解說魚毒試驗

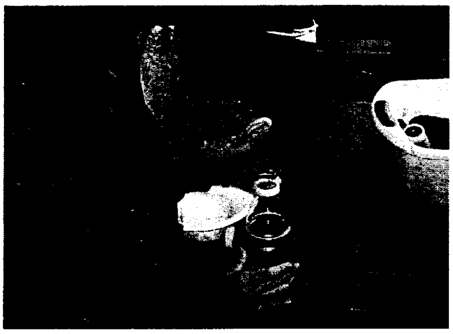
生態教室旁特別搭設採樣觀景台，方便學童進行採樣。

生態教室合影

實地採樣



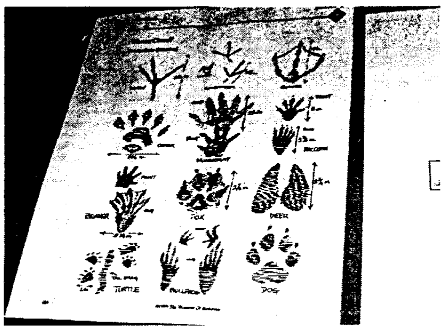
生態教室提供給學童使用的簡易型水中生物放大鏡



水生物觀察

水棲昆蟲圖說

生態教育中心設備及教材



該區域溼地曾發現之動物蹤跡

第四章 加州區域水質管理局考察紀要

舊金山區域水質源管理局 San Francisco Regional Water Quality Control Board（SFBRWQCB）環境水質監測主要進行河川水質監測，監測資料依環保署已規劃之格式，藉由網際網路回傳監測庫資料。

監測項目依季節及河段分布不同而有不同之監測項目及監測頻率。例如冬天河川流量小，部分河川測點即暫停監測。除現場監測項目自行執行外，其他測項則於採樣後另送實驗室分析。WQCB 目前現場水質監測係使用多功能監測系統進行，多功能監測系統的好處在於快速方便且易於攜帶，並具有監測數據儲存功能， WQCB 已使用多年並發展改良該系統使用手冊。

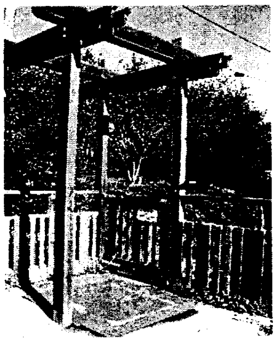
圖四　SFEI 留影紀念

照片右方為美方接待人員，右二係水質監測規劃設計及執行人員 Revital Katznelson, 右一 Anne Senter 係實際執行水質監測的研究助理，目前仍是大學學生。

監測儀器使用前先經校正

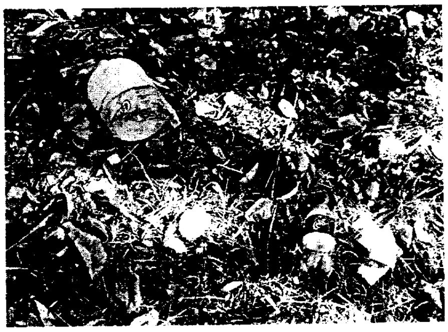
監測儀器外套不繡鋼管加強重量利於河底固定

水質監測點



水質監測點以簡易門禁管制

水質監測情形



紀錄監測點附近廢棄物數量及種類

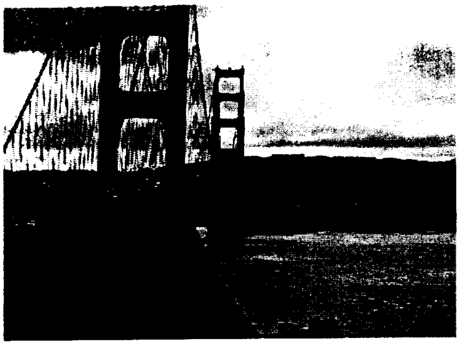
第五章 San Francisco Estuary Institute 考察紀要

San Francisco Estuary Institute 舊金山河口管理委員會係由各領域專家學者所組成之非政府組織，營運管理經費來源由相關產業提撥，類似我國土污基金管理委員會等單位。

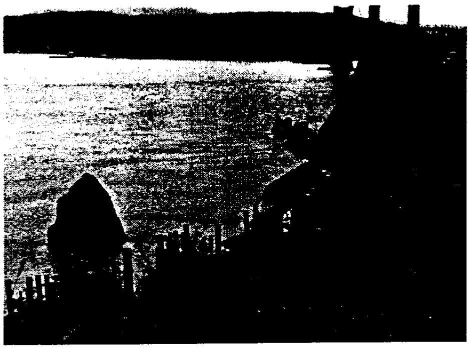
SFEI 主要進行舊金山灣區河口監測，包括舊金山灣附近河川近海及舊金山灣附近水質及底泥監測，監測項目包括一般水質基本測項、PCB、底泥重金屬、牡蠣重金屬等；不同於一般水質監測的是，SFEI 還進行空氣沉降物採樣監測（air deposition sampling），每年都會出版一份舊金山灣水質監測報告。

圖四　SFEI 留影紀念

照片右方 Mike Connor 是 SFEI 經理，左二 Jay Davis,是監測計畫總負責人，左一是 Don Yee 擔任水質監測資料彙整及資料庫管理工作。



著名的舊金山金門大橋



金門大橋也是海域水質採樣點之一

SFEI 門口張貼 2003 年監測摘要海報

會議室觀景窗外的小河也是監測點之一

第六章 考察心得

此行考察雖僅短短十天，但因所訪問的單位均為水質監測實際執行者，對於水質監測及數據分析評估均有豐富經驗，此行或益良多。以下就對於本次考察心得提出幾點建議，提供未來水質監測規劃參考。

一、 在監測執行方面，可參考美方監測執行及分工規劃並發展志工監測，以有效分配監測資源，達到專業分工目的。

美國環保署環境水質監測與我國相同，監測範圍均包括河川、水庫、海域（河口）及休憩海域等水質監測。但美國環保署主要工作內容為監測策略規劃、監測資料庫維護及資料發布。實際水質監測工作則由水資源管理局、SFEI、USGS 以及為數相當龐大之民間企業組成的志工進行，監測分工相當明確。

反觀國內，目前本署環境水質監測係均由監資處統整委託代檢測業執行，監測作業除包括監測策略規劃、監測資料庫維護外尚需負責監測執行及監測技術檢討等工作，負責每月 83 條 294 測站河川水質、每季 57 座水庫(壩）111 個監測點、431 口區域性地下水質監測井及 97 個海域測點監測水質監測作業執行督導及監測數據審核等品保品管工作。作業複雜且負荷相當龐大，可參考美方監測執行及分工規劃並發展志工監測，達到專業分工目的。

另外，在志工參與監測水質方面，近年來我國雖已逐步規劃河川巡守及志工監測推廣，更在 92 年 10 月辦理「參與第一屆世界水質監測日」活動，

邀請中小學生及民眾親生體驗水質監測，得到熱烈迴響與並獲媒體肯定。但與美國企業直接參與水質監測相較之下，志工監測仍是我國未來監測規劃亟需力的一環。

二、 在水體監測評估方面，必須考量不同水體、季節及不同程度之水質進行不同之監測規劃及評估。

美國環保署環境水質監測監測項目依水體、季節及河段分布的不同而有不同之監測項目及監測頻率之彈性。例如舊金山灣河口監測，水質與底質監測點分布就不相同，監測項目亦有所不同。例如，水中含量相當低的重金屬、PCB 等測項就停止水質監測，改採底質監測。在河川水質監測，冬天流量小之河川，即減少監測項目或暫停水質監測。

自九十一年接辦環境水體水質監測以來，監測數據顯示部分水體及水質測質變動不大，且時常發生監測數據太低無法顯示測值的情形，例如河川、水庫、海域及地下水水質重金屬、農藥等均有上述情形。應該仿照美國環保署做法，考量不同水體、不同季節以及不同污染程度之水質進行監測頻率及測項之檢討及多樣性監測評估。

三、 在資料儲存方面，可參考美國環保署水質監測資料之品保控制系統（STORET），健全本署環境監測資料庫。

由於美國環保署對於水質監測資料之採樣及檢驗工作，係委由民間組織

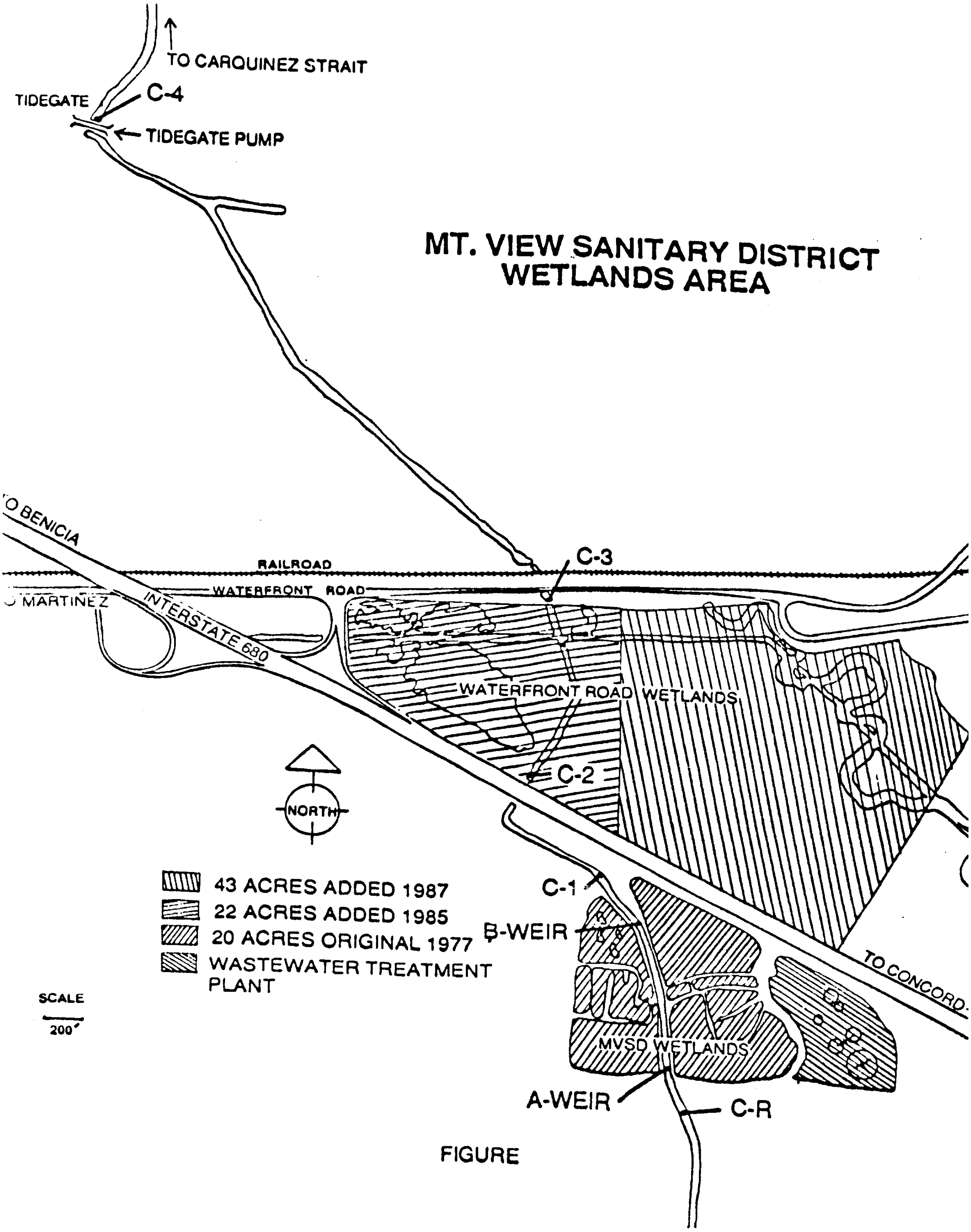
辦理，為能掌握監測資料之品質，除了訂定水質監測標準作業程序外，對於資料鍵入資料庫系統亦有一套完整之規定。美國環保署為彙整全國各區域環保署委外辦理所獲得之水質監測數據，落實水質監測資料之品保控制(QA/QC)，提供各區域環保署一套水質資料管理維護系統（STORET)。

該系統提供委外單位有關水質監測數據資料之匯入功能，各區域環保署人員再利用該系統進行初步之資料篩選，除避免資料載入錯誤外，亦可針對每一筆問題資料下註解(comments)，有效提昇資料品質控管。

各區域環保署定期完成資料蒐集後，可利用該系統檔案上傳功能傳至美國環保署之水質資料倉儲中心，充分應用了「分散處理、集中管理」之資料管理方式，上開流程及管理方式，不但確保了各區域環保署所儲存之水質資料與美國環保署水質資料倉儲中心資料之一致性，也可分擔美國環保署水質資料倉儲中心對於資料品質控管工作，此「分散處理、集中管理」之資料管理方式，將可提供國內辦理環境資料庫相關業務時參考。

附件一

MVSD WETLANDS AREA


TO CARQUINEZ STRAIT
TIDEGATE
C-4
TIDEGATE PUMP
MT. VIEW SANITARY DISTRICT
WETLANDS AREA
TO BENICIA
RAILROAD
C-3
WATERFRONT ROAD
MARTINEZ
INTERSTATE 680
WATERFRONT ROAD WETLANDS
C-2
NORTH
43 ACRES ADDED 1987
22 ACRES ADDED 1985
20 ACRES ORIGINAL 1977
WASTEWATER TREATMENT PLANT
C-1
B-WEIR
TO CONCORD
SCALE
200'
MVSD WETLANDS
A-WEIR
C-R

FIGURE

附件二

2003 PULSE OF THE ESTUARY

The 303(d) List

The San Francisco Regional Water Quality Control Board identifies contaminants of concern in the San Francisco Estuary based on RMP monitoring results and other information. Creation of an impaired water bodies list is required under section 303(d) of the federal Clean Water Act.

The list divides the Estuary into segments and their tributaries that are impaired due to contaminant concentrations that exceed load criteria and impact beneficial uses. The list is revised every four years. In February of 2003 the State Water Resources Control Board (SWRCB) approved the 2002 303(d) list for impaired water bodies within California, including the waters of the Estuary.

This proposal is now under review by the US Environmental Protection Agency, Region IX. The proposed revisions no longer consider copper and nickel as contaminants of concern in the Estuary, except at the mouth of the Petaluma River. Another contaminant of concern in the Petaluma River is diazinon. Stege Marsh in Richmond, Mission and Islais Creeks in San Francisco, and Peyton Slough in Martinez are included in the 303(d) list as impaired due to sediment toxicity.

This is the proposed list for the Estuary and its major tributaries:

Trace elements: Copper (Petaluma River mouth), Mercury, Nickel (Petaluma River mouth), Selenium
Organochlorine pesticides: DDT, Chlordanes, Dieldrin
PCBs
Diazinon
Others: Sediment Toxicity, Dioxins, Furans, Siltation, Pathogens, Nutrients, Exotic species

Potential Threats

The Regional Board, as part of developing the revised 303(d) list, also created for the first time a 303(d) "watch list" of potential threats to water quality. This is a list for contaminants where anecdotal information suggests they may be causing impairment but either the available data are inadequate to draw a conclusion, or the success of the existing regulatory program to control the contaminant is uncertain. Placement on this list is intended to trigger research so more informed decisions can be made in the future. The creation of this new preliminary list was prompted by the National Research Council. At the request of Congress, the NRC reviewed the TMDL process and suggested that this "preliminary list" be developed in addition to the 303(d) list.

This is the preliminary list for 2001 for chemical contaminants in the Estuary:

Copper: San Francisco Bay
Nickel: San Francisco Bay
PAHs: San Francisco Bay
PBDEs: San Francisco Bay
Sediment Toxicity: Central Basin in San Francisco;
Castro Cove in Richmond; Oakland Inner Harbor; San Leandro Bay

www.swrcb.ca.gov/~rwqcb2/download/Tmdl.pdf

monitoring & managing contamination in the san francisco estuary

About This Report

This year marks the tenth anniversary of the San Francisco Estuary Regional Monitoring Program for Trace Substances (RMP). This milestone represents an appropriate time to examine how scientific understanding, regulation, and the degree of contamination in the San Francisco Estuary have changed over the course of a decade. The synthesis of findings from this first phase of the RMP is providing a general theme for the Program in 2003 and 2004. An integrated series of products and events are planned to accomplish an evaluation and long-term summary of the many components of the Program, including:

Short on time? Just look at the figures and captions. They provide key findings in a nutshell.

- the 2003 and 2004 issues of the *Pulse of the Estuary*,
- the 2003 and 2004 RMP Annual Meetings,
- a report summarizing the Program's successes and challenges for the future from a management perspective, and
- a Status and Trends Report that will summarize what has been learned from the RMP and other studies about contamination in the Estuary over the past 10 years.

This issue of the *Pulse* is the first of two consecutive issues dedicated to analysis of the initial 10 years of the RMP. In addition to the usual features of the *Pulse* summarizing the latest data on contamination in the Estuary, this issue contains feature articles focusing on specific components of the multifaceted Program. A particular highlight this year is an article by Jim Cloern and colleagues at USGS that provides an interesting overview of basic ecological lessons learned from 10 years of monitoring water quality in the Bay.

This issue of the *Pulse* has been designed to make information on water quality in the Estuary more accessible. More detailed figure captions have been written that convey the basic take-home messages of each article. Readers that are pressed for time can glean many of the important findings from the *Pulse* by simply reviewing the figures and captions. The Status and Trends Update is now presented entirely as a graphical summary.

The *Pulse of the Estuary* is one of three RMP reporting products. The second product, the *Annual Monitoring Summary*, is distributed via the SFEI web site <www.sfei.org> and includes narrative summaries and comprehensive data tables and charts of the most recent monitoring results. The third product is the *RMP Technical Reports* collection. *RMP Technical Reports* each address a particular RMP study or topic relating to contamination of the Estuary. A list of all RMP technical reports is available at <www.sfei.org>.

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

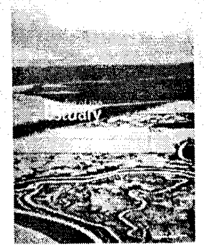
This report should be cited as: San Francisco Estuary Institute (SFEI). 2003. The Pulse of the Estuary: Monitoring and Managing Contamination in the San Francisco Estuary. SFEI Contribution 74. San Francisco Estuary Institute, Oakland, CA.

2000

Premier issue:
- *Introduction to RMP Monitoring*

Feature articles:
- *Top Known Contamination Problems*
- *Contamination of Water, Sediment, and Fish*
- *Summary of Overall Condition*

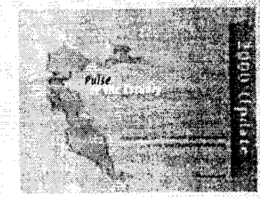
2001



Introduced Pulse feature:
- *San Francisco Estuary Contamination Overview*

Feature articles:
- *Using the RMP to Help Manage the Estuary*
- *Unidentified Contaminants: Hidden Threat?*
- *Tracking Down Contaminant Sources*
- *Analyzing Contaminant Movement and Storage*
- *Improving Contaminant Effects Monitoring*
- *Fitting the RMP into the Monitoring Milieu*

2002

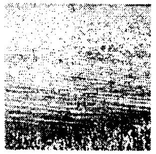


Feature articles:
- *The Five Decade Forecast for PCBs in the Bay*
- *Measuring the Adverse Effects of Contaminants: A New Emphasis*
- *Closing in on Unidentified Contaminants*
- *A New Approach to Sampling Water and Sediment*

Table of Contents

monitoring & management update

feature articles



15
Pulse Highlight: Water Quality Lessons

21
Sediment Dynamics

27
Toxicity Testing

32
10 Years of Pilot and Special Studies

What is the RMP?

An innovative partnership

The RMP has combined shared financial support, direction, and participation by regulatory agencies and the regulated community in a model of collective responsibility. The RMP has established a climate of cooperation and a commitment to participation among a wide range of regulators, dischargers, industry representatives, community activists, and scientists. The RMP provides an open forum for interested parties to communicate about contaminant issues facing the Bay.

An adaptive, long-term program of study in support of management

Stable funding has allowed the RMP to develop an efficient structure that enables the Program to adapt to changing management priorities and advances in scientific understanding. RMP committees and workgroups meet regularly to keep the Program focused on the highest priority issues, efficient, and based on sound science. The RMP has continually improved since its inception in 1993.

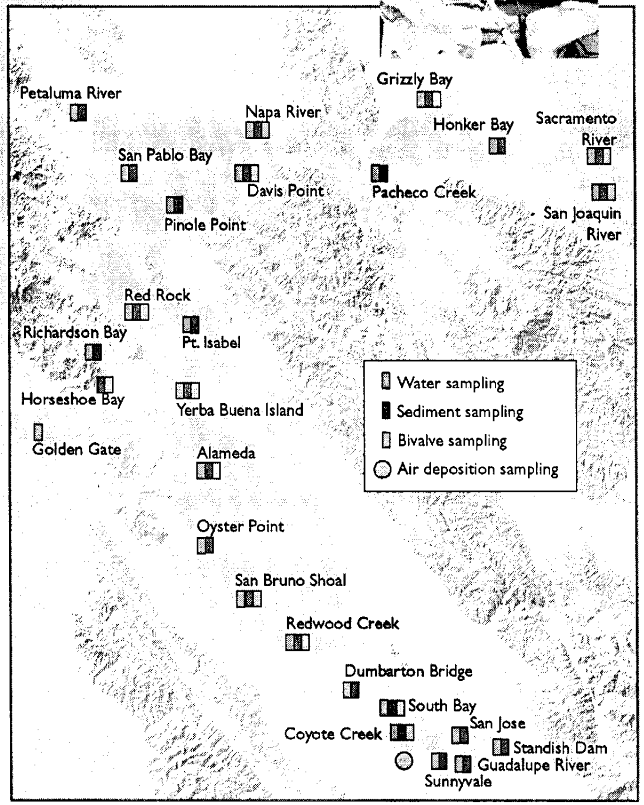
A high quality body of knowledge

The RMP has produced a world-class dataset on estuarine toxic contamination. Monitoring performed in the RMP determines spatial patterns and long term trends in contamination through sampling of water, sediment, bivalves, and fish, and evaluates toxic effects on sensitive organisms and chemical loading to the Bay. The Program combines RMP data with data from other sources to provide for comprehensive assessment of chemical contamination in the Bay.

A portal to information about contamination in San Francisco Bay

The RMP provides information targeted at the highest priority questions faced by managers of the Bay. The RMP produces an annual report (the *Pulse of the Estuary*) that summarizes the current state of the Estuary with regard to contamination, a quarterly newsletter, technical reports that document specific studies and synthesize information from diverse sources, and journal publications that disseminate RMP results to the world's scientific community. The RMP web site provides access to RMP products and links to other sources of information about water quality in San Francisco Bay.

Water sampling

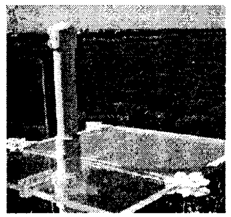


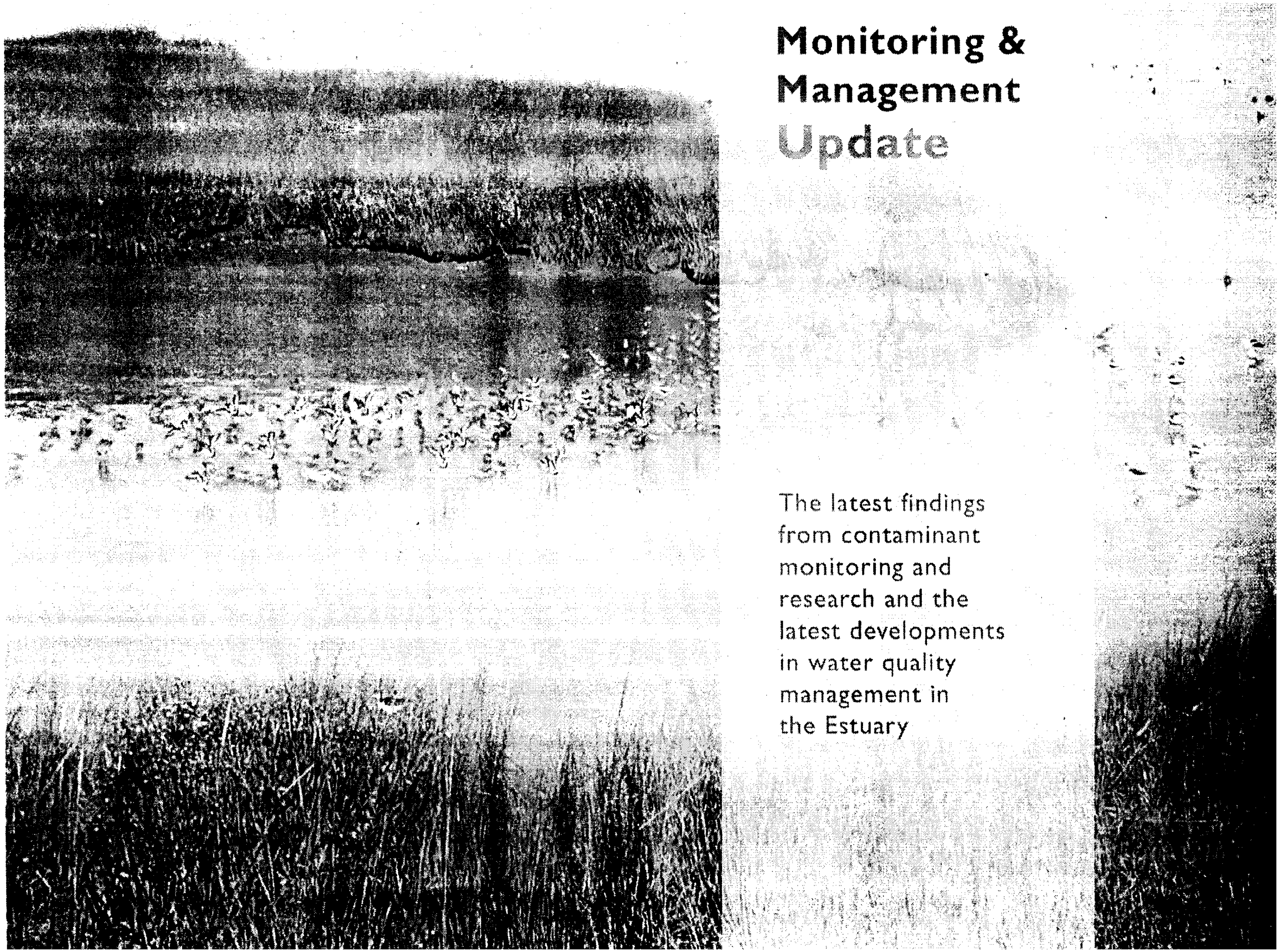
RMP Sampling Locations
2001

Sediment sampling

Bivalve sampling

Air deposition sampling





Monitoring & Management Update

The latest findings from contaminant monitoring and research and the latest developments in water quality management in the Estuary

INTRODUCTION

The **Status and Trends Update** is a presentation of graphical information on the present degree and distribution of contamination in the Estuary (status) and variation in contamination over time (trends). This summary incorporates the latest RMP findings, with a focus on the contaminants that are presently of greatest concern. In addition, this section includes data from studies outside the RMP. Inclusion of these other sources of information allows the *Pulse* to provide a more complete picture of contamination in the Estuary and its watershed. This issue includes a series of graphs from the U.S. Geological Survey (USGS) Ecology and Contaminants Project <http://wwwrcamnl.wr.usgs.gov/tracel/>. The USGS has conducted contaminant monitoring in the Estuary for many years. One emphasis of the USGS program has been evaluation of accumulation of trace elements in clams. Their monthly sampling complements the RMP by providing information on short-term variation that is essential to interpreting results from annual RMP sampling. Long-term monitoring by USGS is one of the primary sources of trend information for the Estuary. The CALFED Mercury Project is another important source of recent information on contamination in the Estuary, with a focus on the Delta–the freshwater portion of the Estuary. The CALFED Mercury Project was an intensive, multifaceted investigation of mercury sources, fate, and effects in the Delta. The two figures from the Project presented here illustrate the long-term persistence and broad spatial extent of the mercury problem in the Estuary and its watershed.

The **Current Status of Bay TMDLs** is an update on managing contaminants in the Estuary. The TMDL process is the regulatory framework used by the San Francisco Bay Regional Water Quality Control Board and stakeholders in the watershed to tackle the challenging problem of reducing the negative impacts of mercury, PCBs, and other priority contaminants on the Estuary.

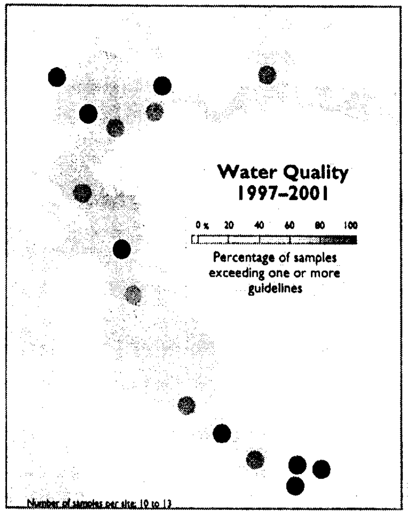
CONTAMINANT GUIDELINES

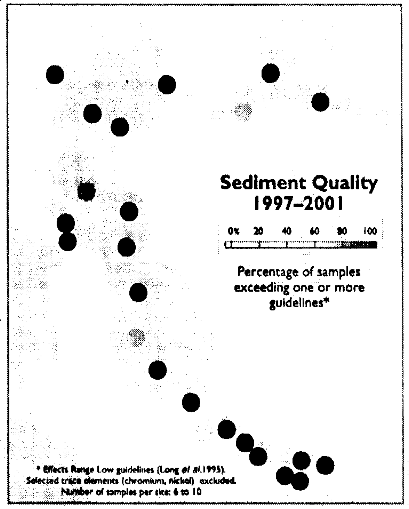
Contaminant guidelines* are generally intended to indicate if water or sediment is safe. Water and sediment are safe when those things we value (e.g., wildlife, being able to eat fish we catch, or ecosystem functions) are being protected.

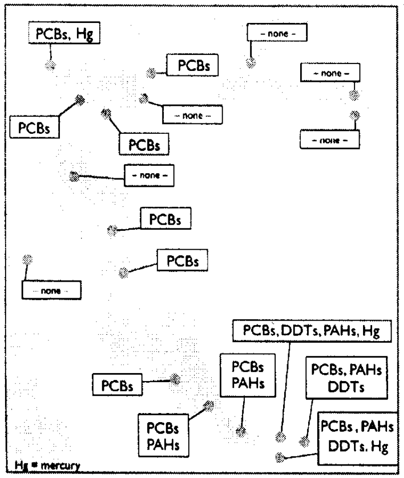
Guidelines provide a way to connect monitoring results, which are just numbers, with judgments on the condition of the environment. It is a daunting task to figure out just how high is too high when referring to contaminant levels in the Estuary. It is assumed that all organisms can tolerate some level of exposure to contaminants, but if that exposure gets too high, an "adverse effect," such as abnormal embryo development or death, will occur. Guidelines are set to protect Estuary wildlife and humans from adverse effects.

Continued on page 9

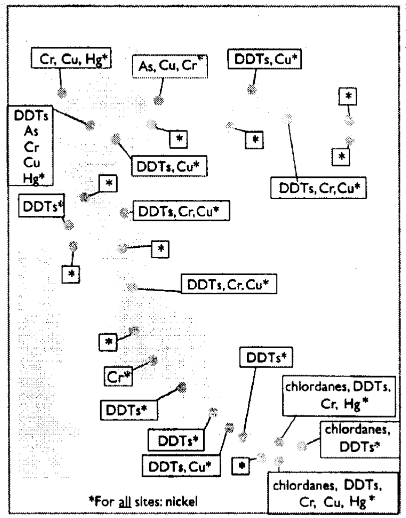
** In this report, the general term guideline is used to refer to several types of environmental quality benchmarks, from legally enforceable water quality criteria to unofficial benchmarks such as the Effects Range values for sediment (Long et al. 1995).*







Water contaminants frequently (>90% of the time) exceeding their guideline (1997–2001)

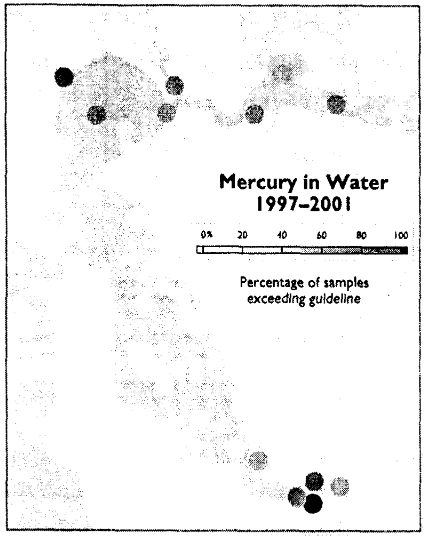


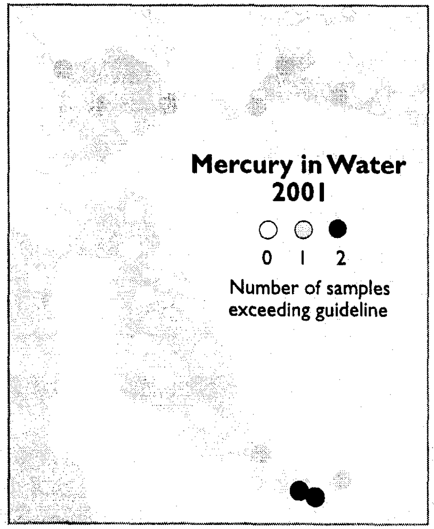
As=arsenic, Cr=chromium,
Cu=copper, Hg=mercury, *=nickel

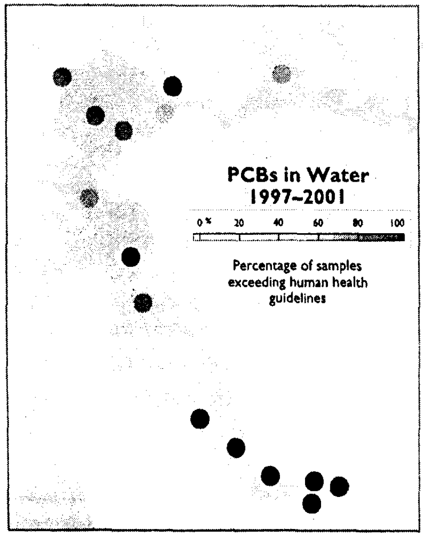
Sediment contaminants frequently (>90% of the time) exceeding their guideline (1997–2001).

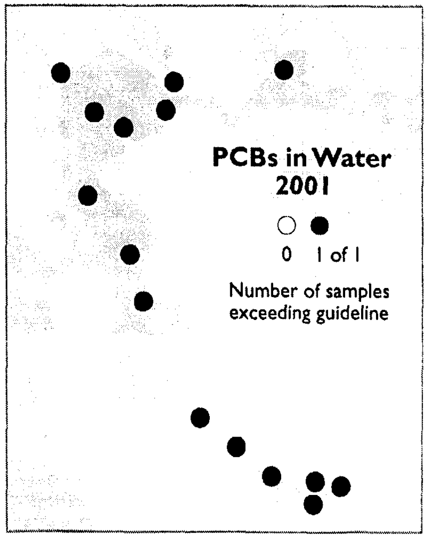
A few problem contaminants are widespread in the Estuary.

While the water and sediment of the Estuary meet cleanliness guidelines for most contaminants, a few problem contaminants are widespread. From 1997-2001, 61% of water samples analyzed in the RMP contained at least one contaminant at a concentration exceeding its water quality objective (top left). PCBs, PAHs, and mercury accounted for most of these exceedances (bottom left). For sediment, 90% of samples collected from 1997-2001 exceeded a threshold for possible effects on aquatic organisms (top right). Sediment contaminants that commonly exceeded their guideline included the organochlorine pesticides DDT and chlordane and the trace elements arsenic, chromium, copper, nickel, and mercury (bottom right). Contamination is not spread evenly throughout the Estuary. Overall, monitoring sites in the lower South Bay, the Petaluma and Napa River mouths, San Pablo Bay, and Grizzly Bay are more contaminated than other sites. The South Bay sloughs are particularly contaminated.



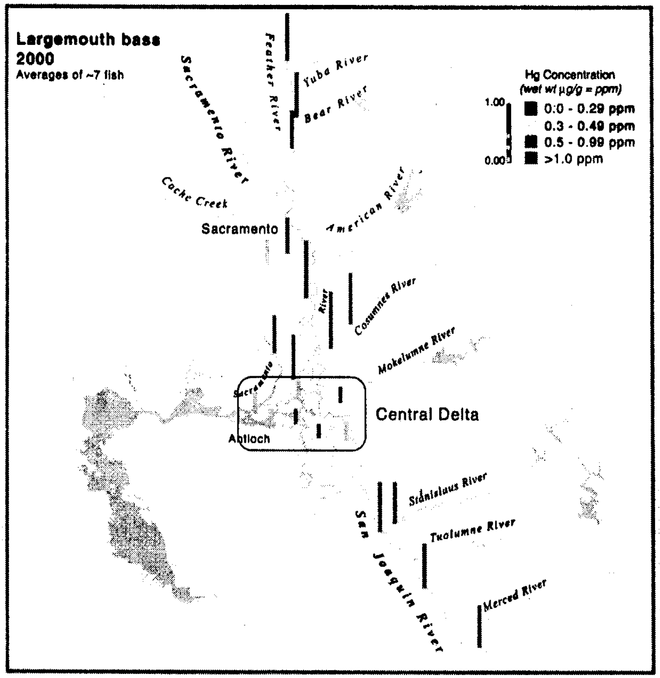


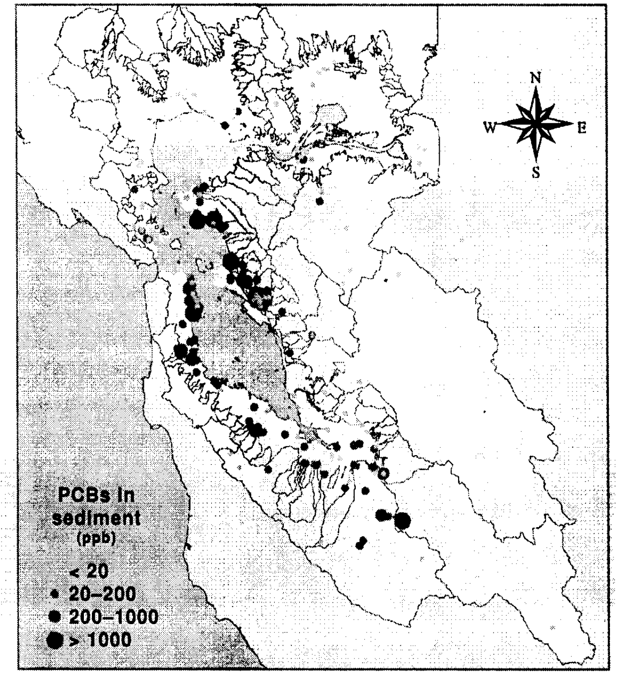




Mercury contamination is a major concern in the Estuary, and a high priority with the San Francisco Bay Regional Water Quality Control Board for clean-up action. Mercury is a problem because it accumulates to high concentrations in Estuary fish and wildlife. Humans and wildlife that consume Estuary fish face the greatest health risks due to mercury exposure. A water quality objective has been established for mercury that is designed to prevent accumulation of unacceptable concentrations in fish. The total mercury water quality objective was exceeded in 38% of samples collected from 1997 – 2001 (left) and 24% of the samples collected in 2001 (right). The RMP has consistently found elevated concentrations of mercury in water and sediment near the mouth of the Guadalupe River, attributable to the historic New Almaden mining district. The high concentrations of mercury observed near the mouth of the Petaluma River are due in part to the presence of a cloud of suspended sediment that is resuspended and deposited at this location with every tidal cycle (see Schoellhamer article page 21).

PCB contamination remains one of the greatest concerns in the Estuary, and is also a primary focus of clean-up efforts by the Regional Water Quality Control Board. Like mercury, PCBs are a problem because they accumulate to high concentrations in Bay fish and pose health risks to consumers of Bay fish. A water quality objective has been established for PCB concentrations in water to prevent unacceptable accumulation of PCBs in fish. This PCB water quality objective was exceeded in 79% of samples collected from 1997 – 2001 (left). PCB contamination is greatest in the South Bay; all samples collected in the South Bay during this period exceeded the objective. The original source of this contamination is not known. In 2001, 15 of 18 (83%) samples exceeded the objective (right).





The mercury problem extends to the freshwater portion of the Estuary

and through large portions of the Bay-Delta watershed. Largemouth bass is a popular sport fish species and a valuable indicator of mercury contamination in the freshwater portion of the Estuary. Mercury concentrations in largemouth bass in hundreds of river miles of the Sacramento and San Joaquin river basins have been found to be well above the 0.3 ppm threshold for potential human health concern. Some good news, however, is that concentrations in the central Delta are significantly lower and frequently below the 0.3 ppm threshold. The reason for the sharp drop in mercury in the central Delta waters is not yet understood. Other good news is that some other species, such as bluegill, generally do not accumulate mercury to concentrations of concern.

Reference: Davis, J.A., B.K. Greenfield, G. Ichikawa, and M. Stephenson. 2002. Draft report: Mercury in Sport Fish from the Delta Region. San Francisco Estuary Institute, Oakland, CA.

Contact: Jay Davis, San Francisco Estuary Institute, jay@sfei.org

Local watersheds are important sources of PCBs to the Estuary.

Urban runoff from small tributaries around the Estuary has been identified as one of the main pathways for continuing input of PCBs. A recent survey of PCB contamination in sediment from creeks and storm drains (2000), when combined with sediment data from sampling in the Bay (1991–1999), begins to point to continuing sources of PCBs in the Bay watershed. These data can be reviewed in more detail and compared to land use and other information on the web at: <http://www.ecoatlas.org/custom/pcbtool.html>

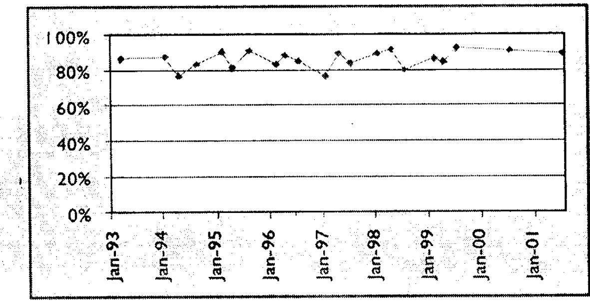
Reference: McKee, L., Leatherbarrow, J., Newland, S., and Davis, J. 2002. Draft Report: A review of urban runoff processes in the Bay Area: Existing knowledge, conceptual models, and monitoring recommendations. SFEI Contribution 66. San Francisco Estuary Institute, Oakland, CA.

Contact: Jon Leatherbarrow, San Francisco Estuary Institute, jon@sfei.org

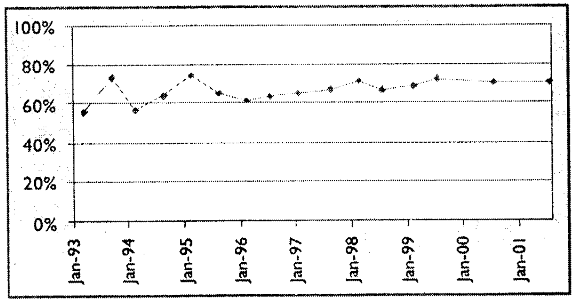
Progress Toward Meeting Contaminant Guidelines

Most contaminant guidelines are being met. A relatively small number of problem contaminants make it rare to find water or sediment in the Estuary that is completely clean. There has been no obvious improvement in recent years. Achieving greater compliance with water and sediment guidelines poses a great challenge, largely because the Estuary is inherently slow to respond to reductions in inputs of persistent contaminants and because many problem contaminants have been distributed throughout the Estuary and its watershed.

Water



Sediment



These charts were created by calculating, for each sampling period and contaminant, the percentage of samples that met the guideline. Results for each contaminant were then averaged within each sampling period to obtain the values plotted on the chart.

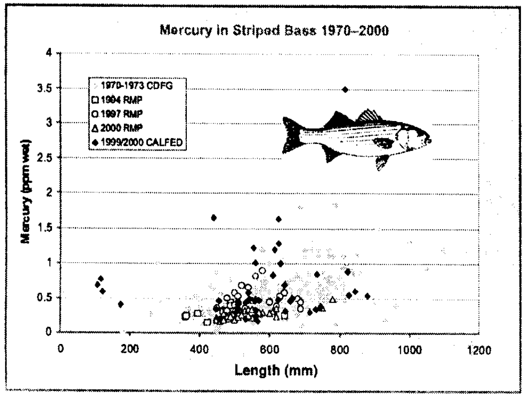
A value of 100% would mean all water or sediment samples met guidelines for all monitored contaminants.

Polychlorinated Biphenyls (PCBs)

PCBs are a group of over 200 organic chemicals with a number of characteristics that made them useful to industry. Manufactured from 1929 to 1979, PCBs were primarily used as hydraulic fluids, lubricants, plasticizers, in electrical transformers, and in carbonless copy paper. Smaller quantities were also used as pesticide extenders and in inks, waxes, and other products.

Growing awareness of the environmental impacts of PCBs, including their persistence and accumulation in animal tissue, led to a ban on their sale and production in the United States in 1979. Enclosed uses, such as in electrical transformers, are still permitted, and thousands of kilograms are known to be in use in the Bay Area. The bulk of the current PCB problem in the Estuary is believed to stem from activities prior to the 1979 ban.

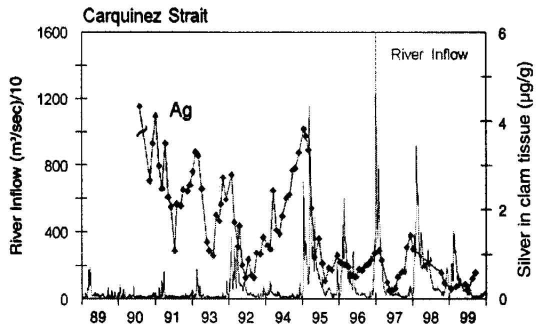
PCBs are found at higher concentrations in animals that are higher in the food web. Therefore, predatory fish, birds, and mammals near the top of the food web, including humans that consume fish, are particularly vulnerable to the accumulation and effects of PCB contamination. Individual PCBs vary in their toxicity, but in general PCBs are extremely toxic in long-term exposures and can cause developmental abnormalities, disruption of endocrine system functions, impairment of immune function, and cancer.



Mercury concentrations in striped bass from the Estuary have shown little or no change in 30 years. One of the primary reasons for concern with regard to mercury is accumulation in Estuary sport fish and the associated fish consumption advisory. A consumption advisory related to mercury contamination in striped bass in the Estuary has been in place since 1970. In recent years the RMP and the CALFED Mercury Project have measured mercury in striped bass. These recent data can be compared to the data from the early 1970s. Size of the fish must be taken into account, as mercury reaches higher concentrations in larger, older fish. Mercury concentrations in samples collected in recent years are not appreciably different from the concentrations measured 30 years ago. In fact, some of the recently measured concentrations are high even relative to the historic data. These data suggest that the degree of mercury contamination in the Estuary food web is not declining.

Reference: Davis, J.A., B.K. Greenfield, G. Ichikawa, and M. Stephenson. 2002. Draft report: Mercury in Sport Fish from the Delta Region. San Francisco Estuary Institute, Oakland, CA.

Contact: Jay Davis, San Francisco Estuary Institute, jay@sfei.org



Silver accumulation has been associated with reduced reproduction in clams. Silver is not currently included on the 303(d) list of contaminants of concern, but a 2003 publication by U.S. Geological Survey researchers concluded that silver probably caused reduced reproductive activity in North Bay clams in the 1990s. The report was based on an excellent long term dataset showing trends in silver concentrations in clams (the exotic species *Potamocorbula amurensis*) from 1990 through 1999. Silver concentrations in the clams were found to be related to freshwater flows into the Estuary, with concentrations building up during dry periods and declining rapidly after major freshwater inputs. Monthly evaluation of reproductive status (gonad histology) found reduced reproduction when silver concentrations in the clams were above 2 µg/g dry weight. No other measured environmental variables appeared to be linked to the reduced reproduction.

Reference: Brown, C.L., Parchaso, F., Thompson, J.K., and Luoma, S.N. 2003. Assessing toxicant effects in a complex estuary: A case study of effects of silver on reproduction in the bivalve, Potamocorbula amurensis, in San Francisco Bay. Human and Ecological Risk Assessment 9: 95-119.

Contact: Cynthia Brown, U.S. Geological Survey, clbrown@usgs.gov

Continued from page 4

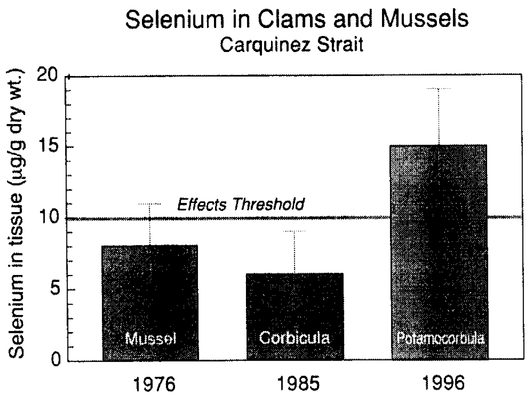
Of course, what is too high for some organisms may be perfectly tolerable for others. Natural factors also can have an influence; what is too high at one temperature or salinity may be tolerable at another. Contaminant mixtures can also act additively or synergistically, causing adverse effects even if the contaminant levels taken individually are safe.

Given these variables, setting a proper guideline is a challenging and inexact task. Guidelines can change as new information becomes available that indicates a guideline is not protective enough or is inappropriately low compared to natural concentrations. RMP results have helped determine if guidelines are set appropriately. Most guidelines were created for use throughout the state or nation, not specifically for the Estuary. Guidelines specific to the Estuary have been developed for some contaminants. For water, guideline development incorporates both laboratory studies and field observations, and is designed to protect a particular set of qualities we value, known in the California Water Code as "beneficial uses." Water quality guidelines are intended to protect most organisms most of the time, not all organisms all of the time. The Regional Water Quality Control Board, a state agency, sets water quality objectives with guidance from the U.S. Environmental Protection Agency. In 2000, the water quality objectives for the Estuary were revised. The revised values, collectively known as the California Toxics Rule, are used in this report. For a list

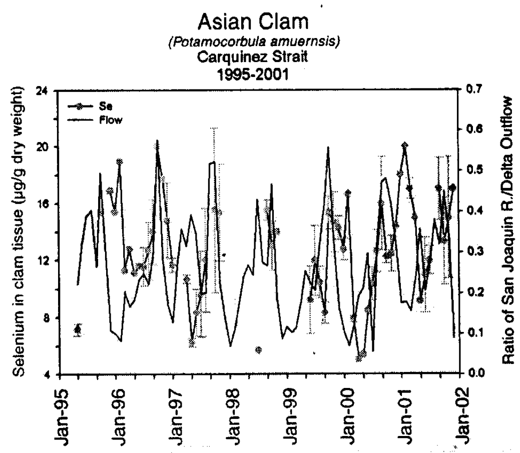
Continued on next page

Continued from page 9

of the values, see <http://www.sfei.org/rmp/2000/2000_Annual_Results.htm>. For sediment, the guidelines used in the maps of this report ("Effects Range Low" or ERLs) are based on a study that compiled many observations of adverse effects on organisms in laboratories and natural settings around the world (Long et al. 1995). Using ERLs sets a high standard for Estuary cleanliness. For a list of the values, see <http://www.sfei.org/rmp/2000/2000_Annual_Results.htm>.



Changes in the aquatic community may increase selenium risks to wildlife and humans. 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. Consumption advisories for surf scoter and scaup have been in effect since 1986 and 1988, respectively, and this is a primary reason for the inclusion of selenium on the 303(d) list (see Inside Back Cover). A 2002 article by the U.S. Geological Survey (USGS) concluded that the invasion of the Bay by an exotic clam, *Potamocorbula amurensis,* that accumulates higher selenium concentrations than other bivalve species has increased the selenium threat to humans and wildlife. This clam has become a dominant member of the Bay food web and is an important prey item for surf scoters, sturgeon, and other species. The average selenium concentration in *Potamocorbula* in 1996 was well above the 10 µg/g dry weight threshold for possible effects on wildlife species consuming *Potamocorbula.*



Selenium concentrations in the northern Estuary fluctuate seasonally, but are not increasing or decreasing over the long term. Understanding how bioaccumulation occurs in *Potamocorbula* is essential to evaluating the impact of future changes in selenium discharges to the Estuary. Since 1995, the USGS has measured selenium concentrations in *Potamocorbula* on a monthly basis to better understand factors influencing variability over time. Despite an overall reduction since 1998 in the concentrations of selenium in waters of the Estuary and in the proportion of the more bioavailable form of selenium ("selenite"), concentrations in *Potamocorbula* have not changed. Further studies are underway to determine the nature of the relationship between selenium inputs to the Estuary, river flow, and selenium uptake by *Potamocorbula.*

References for above figures:

Linville, R., Luoma, S.N., Cutter, L., and Cutter, G. A. 2002. Increased selenium threat as a result of invasion of the exotic bivalve Potamocorbula amurensis in the San Francisco Bay. Aquatic Toxicology 57: 51-64.

Contacts: Sam Luoma, U.S. Geological Survey, snluoma@usgs.gov, Robin Stewart, U.S. Geological Survey, arstewar@usgs.gov

The Current Status of Bay TMDLs

Dyan Whyte (dcw@rb2.swrcb.ca.gov) – San Francisco Bay Regional Water Quality Control Board, Oakland, CA

Total Maximum Daily Loads (TMDLs) are plans with numerical goals designed to attain and maintain water quality standards. The TMDL requirements set forth in the Clean Water Act require the San Francisco Bay Regional Water Quality Control Board (Regional Board) to develop solutions to San Francisco Bay's most challenging water quality problems. The overarching objective is to ensure that TMDL efforts result in tangible water quality improvements in the shortest possible time with the goal of restoring and maintaining the water quality standards of impaired waters. As such, the Regional Board strives to balance and optimize Regional Board staff efforts on the required elements of a TMDL within this perspective.

Baseline data from the RMP, RMP pilot and special studies, and studies funded by the recently formed Clean Estuary Partnership (CEP, see page 12) are invaluable for improving the technical basis of San Francisco Bay TMDLs and focusing implementation strategies towards actions that should truly make a difference. Each TMDL will include an adaptive implementation plan which sets forth feasible, reasonable, and effective actions that will lead to water quality improvements and identify studies needed to confirm key assumptions and resolve key uncertainties concerning fate, transport, and effects processes. Adaptive implementation is founded on the premise that implementing actions and observing the Bay response will provide the dual optimum benefit of defining effectiveness and improving our understanding of the Bay system.

The following discussion highlights progress and noteworthy findings on San Francisco Bay TMDL projects. Please visit <www.swrcb.ca.gov/rwqcb2/> for additional information on TMDLs and to obtain copies of TMDL reports.

Copper and Nickel

One positive outcome of the TMDL process can be a finding of no impairment and a subsequent delisting of a waterbody. This is the case for copper and nickel in San Francisco Bay. In February 2002, the State recommended removing all San Francisco Bay segments from the State's list of impaired waters (Clean Water Act 303(d) list, see Inside Back Cover) for copper and nickel. Bay-wide copper and nickel monitoring data, collected by the RMP over the last decade, helped to inform this finding. The South San Francisco Bay aspect of this decision exemplifies how stakeholder and Regional Board collaboration, coupled with the application of sound science and adequate funding, led to the development of site-specific objectives for San Francisco Bay and a finding that Bay waters do not exceed objectives. Another key to this success was the commitment by dischargers and stakeholders to implement preventive actions to assure that copper and nickel concentrations do not increase and that beneficial uses remain protected. A similar effort is underway for Bay segments north of the Dumbarton Bridge.

Mercury

The overarching goal of the San Francisco Bay mercury TMDL is to reduce mercury concentrations in biota such that fish, wildlife, and humans who consume Bay fish are protected. Regional Board efforts that began in 1998 are nearing completion with publication of a final TMDL report anticipated in spring 2003. Public comments received on this final report will be considered as key TMDL provisions are formally incorporated into the Basin Plan.

The final TMDL report proposes three numeric targets to define the solution to the San Francisco Bay mercury impairment problem: a fish tissue mercury concentration target to protect humans who consume Bay fish; an avian egg mercury concentration target to protect sensitive wildlife; and a sediment mercury concentration target to bring the Bay into compliance with water quality objectives. Meeting the proposed targets will require reducing mercury levels in sediment, fish, and bird eggs by about 50%.

The San Francisco Bay mercury implementation plan sets forth steps for achieving the TMDL targets and has four principal objectives:

1. reduce existing and future controllable discharges of mercury;
2. reduce the amount of methylmercury produced and the potential for bioaccumulation;
3. plot a course for addressing key scientific uncertainties and improve our understanding of the ecosystem; and
4. encourage actions that reduce loads of multiple pollutants.

Likely implementation actions include:

1. cleaning up the Guadalupe River and Central Valley watersheds mining legacies;
2. implementing BMPs and sediment control for urban runoff;
3. investigating the controllability of atmospheric deposition;

The Clean Water Act and TMDLs

The Clean Water Act recognizes that every body of water provides benefits that are valuable and worth protecting. The beneficial uses of a particular water body might include, for example, catching and eating fish, swimming, and drinking. Such uses require good water quality. Traditional management of water quality centers on maintaining standards for the cleanliness of wastewater. In some places this approach successfully protects the uses of a water body, but in others it does not. Water bodies that continue to lack the water quality necessary for supporting their designated uses are considered "impaired waters." Each state is required to develop a list of impaired waters and the contaminants that impair them (known as the "303(d) list," after the corresponding section of the Clean Water Act). Under the Clean Water Act, cleanup plans known as Total Maximum Daily Loads (TMDLs) must be developed for all impaired waters. The TMDL process takes a more comprehensive view of water quality by identifying all contaminant inputs to the water body, determining the total input the water body can handle, and designating particular inputs that need reduction.

4. reducing in-bay dredged material disposal; and
5. implementing measures to reduce the production of methylmercury.

RMP special studies and status and trends monitoring, and CEP-funded studies substantially improved the technical basis of this complex TMDL. The RMP's Mallard Island/Central Valley drainage contaminant load estimates, mercury atmospheric deposition study, estuarine sediment transport studies, and water and fish contaminant data sets all enhanced the scientific understanding of the problem and were used to propose TMDL mercury targets. The CEP studies are also playing a key role in identifying effective implementation actions. In the future, the Regional Board will rely on the RMP for ongoing monitoring and assessments to evaluate progress towards attaining TMDL targets and to help guide effective implementation actions.

PCBs

In addition to mercury, the Regional Board is concerned with PCB concentrations in San Francisco Bay fish and the threat they pose to human health and wildlife. A preliminary PCB TMDL report, anticipated for release in spring 2003, will describe water quality concerns and potential solutions. The Regional Board will encourage stakeholders to review this report and comment on the scientific basis of the technical TMDL and implementation alternatives.

Clean Estuary Partnership

The San Francisco Bay Regional Water Quality Control Board, the Bay Area Clean Water Agencies, and the Bay Area Stormwater Management Agencies Association have signed a Memorandum of Understanding reflecting their belief that a collaborative approach for developing TMDLs will be the most effective method for achieving sustainable water quality benefits for the Bay. The Clean Estuary Partnership (CEP) formed to implement the intent of this Memorandum of Understanding.

The mission of the Clean Estuary Partnership is to use sound science, adaptive management, and public collaboration to develop and implement technically valid and cost-effective strategies including TMDLs that result in identifiable, sustainable water quality improvements for San Francisco Bay. Please visit <www.cleanestuary.org> for more information about the CEP, to obtain copies of CEP reports, and to find out how you can become more involved in this program.

PCB sources and loadings analyses suggest that the Bay ecosystem is dominated by the large amount of PCBs already in the sediments. Urban runoff and inflow from the Sacramento-San Joaquin Delta are estimated to be the major external loads to the system. A predictive model of the long-term fate of PCBs in the Bay developed under the RMP indicates that even small reductions in current PCBs loads will greatly accelerate the recovery of the Bay. A collaborative effort between SFEI (on behalf of RMP) and USGS is underway to enhance the modeling of the long-term fate of PCBs in the Bay that will better incorporate sediment dynamics and sources. SFEI has also collaborated with other scientists in a RMP effort to develop a Bay-specific food web model. This model should provide a predictive tool to relate sediment and water PCB concentrations to fish tissue PCB concentrations, and help focus our implementation actions.

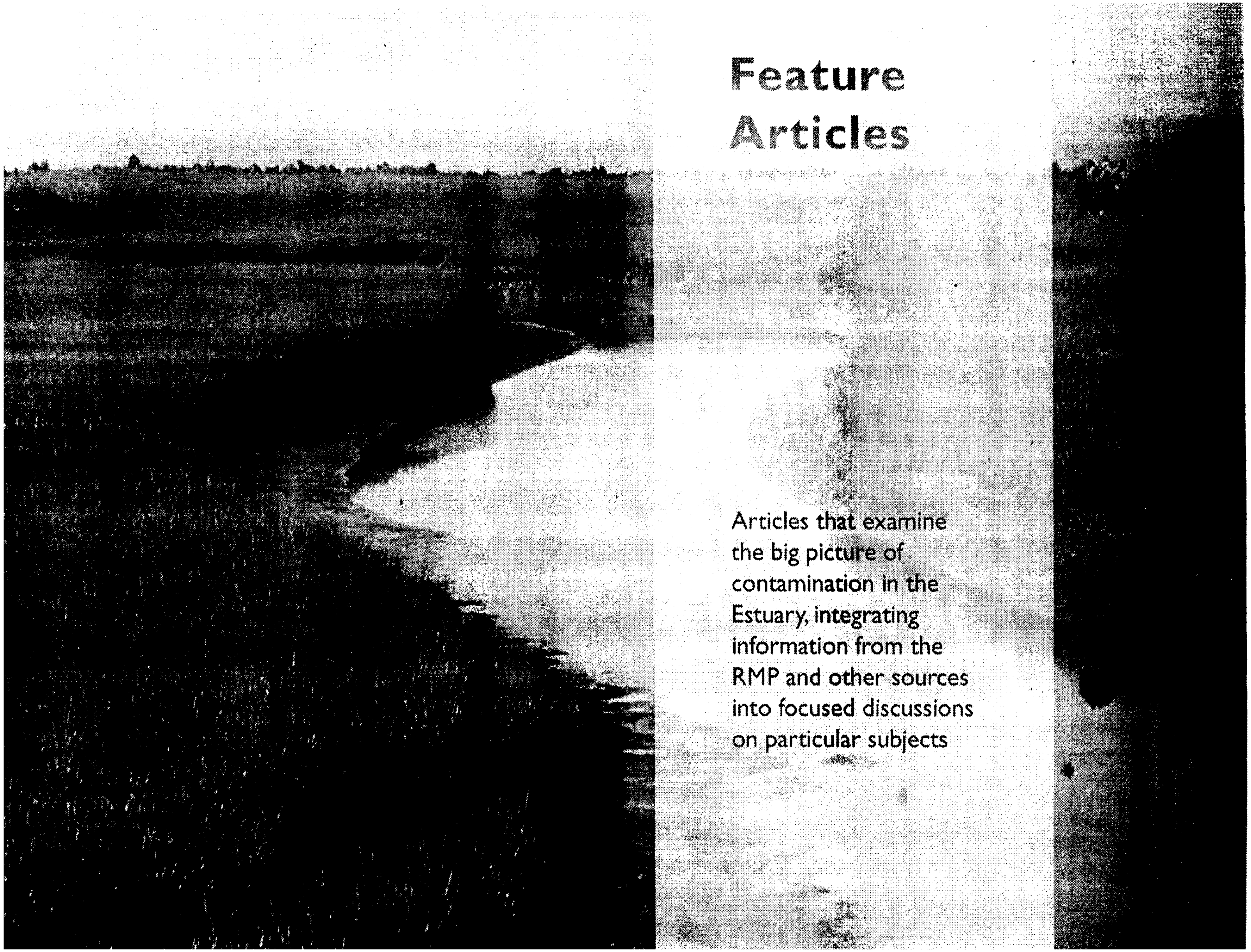
The PCB TMDL implementation strategy will likely entail reducing PCB loads to the Bay by cleaning up contaminated sediments in storm drains and controlling future PCB discharges to storm drains from upland source areas, and by remediating contaminated "hot spots" on the Bay margin.

Other 303(d) Contaminants

San Francisco Bay is also listed as impaired due to selenium, legacy pesticides, diazinon, and although not formally listed, PBDEs and PAHs are on a watch list of contaminants that may soon emerge as a water quality concern (see Inside Back Cover). Through the RMP, the Regional Board hopes to track the status and trends of these pollutants. The CEP plans to develop simple conceptual models that reflect the scientific understanding of how these stressors move through the environment, compile existing data on the extent and severity of impairment, and develop lists of key management questions.

The Regional Board is finally realizing significant progress towards developing TMDLs, and for some pollutants, early implementation actions are underway. The Regional Board is confident that with continued assistance from the RMP and CEP and a collaborative stakeholder process we will achieve our goals.

Feature Articles



Articles that examine the big picture of contamination in the Estuary, integrating information from the RMP and other sources into focused discussions on particular subjects

Introduction

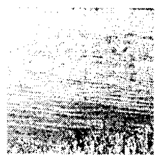
In this issue and the next issue of the *Pulse* this section will contain articles that synthesize information from the past ten years of water quality studies of the Estuary. In this issue the focus is on the intensive monitoring of basic water quality parameters and toxicity that have been components of the RMP from the inception of the Program. Next year's issue of the *Pulse* will focus on results from long term monitoring of chemical concentrations in the water, sediment, and food web of the Estuary.

The U.S. Geological Survey (USGS) has been a partner in the RMP from the beginning, combining funding from RMP with other sources to provide detailed insights into ecological processes in the Estuary. USGS monitoring of basic water quality parameters (page 15) has documented significant long term changes in the ecology of the Estuary in the past ten years, including improvements in the oxygen content of Bay waters related to improved sewage treatment and the extraordinary impact of the invasive Asian clam (*Potamocorbula amurensis*) on the food web. This article was designated a Pulse Highlight because it provides a readily understandable introduction to the basic ecology of the Estuary.

Detailed USGS investigations of sediment dynamics in the Estuary and sediment supply from the watershed (page 21) have yielded important insights regarding contaminant fluctuations over the short term and fate over the long term. Sediment is becoming a scarce resource in the Estuary. Reduced sediment supply and increased demand for sediment from the Airport extension, the Cargill salt pond restoration project, and other large scale restoration projects will lead to erosion of sediment from the bottom of the Bay and possibly degrade water quality.

Researchers from the Granite Canyon Marine Laboratory, Pacific EcoRisk, and SFEI present a summary of ten years of toxicity testing on page 27. The frequent occurrence of toxicity in water and sediment of the Estuary has been a major concern. A management highlight from the past ten years is the observation of an apparent reduction in toxicity in water, possibly associated with reduced use of organophosphate insecticides. A new concern has arisen, however, over the possible ecological impacts of the pyrethroid insecticides that are being used as replacements for the organophosphates. The evolution of the toxicity testing element during the past ten years provides an excellent example of how the RMP has adapted to in response to changes in our state of knowledge and conditions in the Estuary.

Adaptation of the RMP is also the theme of an article summarizing the diverse array of Pilot and Special Studies conducted by the Program in the past ten years (page 32). These studies have produced a significant body of knowledge and provided an important mechanism for the Program to continually increase its relevance to managing contamination in the Estuary.



Lessons from Monitoring Water Quality in San Francisco Bay

James E. Cloern (jecloern@usgs.gov), Tara S. Schraga, Cary B. Lopez, and Rochelle Labiosa — U.S. Geological Survey, Menlo Park, CA

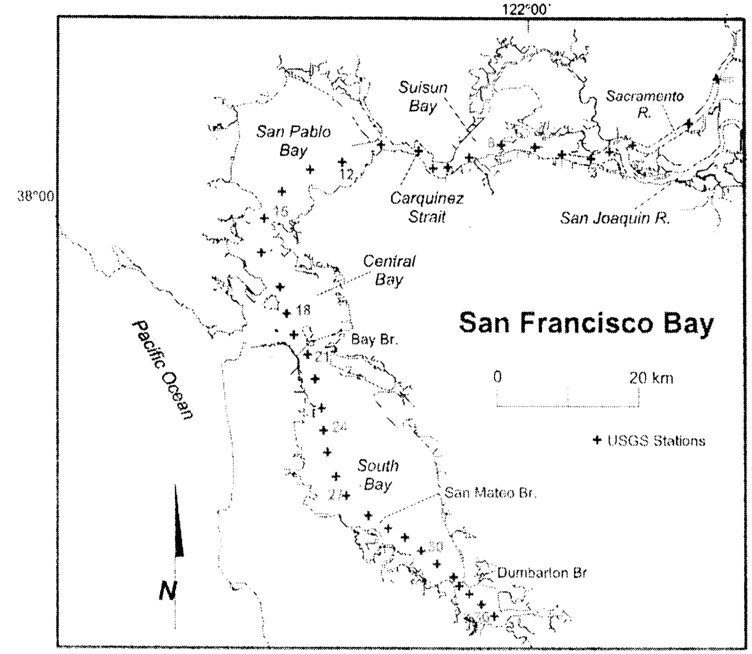


Figure 1. Monitoring of basic water quality parameters. The USGS, in cooperation with RMP, measures basic water quality indicators every month at 38 stations between the Sacramento River and South Bay with additional weekly sampling in the South Bay during spring. Submersible instruments measure salinity, temperature, suspended solids, light penetration, dissolved oxygen, and chlorophyll a from the water surface to the bottom. This basic information provides a foundation for understanding variability in the sources, transport, bioaccumulation, and ecosystem effects of contaminants in San Francisco Bay.

INTRODUCTION

San Francisco Bay is the defining landscape feature of the place we call 'The Bay Area,' but most of us only experience the Bay as we view it from an airplane window or drive across one of its bridges. These views from afar suggest that the Bay is static and sterile, but this impression is deceptive. If you are one of the many thousands of students who have experienced the Bay through a school excursion with the Marine Science Institute or other educational programs, you observed its rich plankton soup under a microscope, sorted clams and worms and crustaceans from mud samples, and identified the gobies, sole, halibut, bat rays, sharks, sardines, and smelt caught with trawls. San Francisco Bay is much more than a landscape feature. It is a dynamic ecosystem, continually changing and teeming with life. The Bay once supported the most valuable fisheries on the west coast of the United States, but commercial fishing for shellfish, shrimp, sturgeon, shad, salmon, and striped bass ended many decades ago because of habitat loss, pollution, invasive species and over harvest.

Bay Area residents feel a sense of responsibility to protect San Francisco Bay and keep it healthy. Some even dream about the recovery of fish stocks so they can sustain commercial fishing once again inside the Bay. How is our Bay doing? Is it highly polluted or pretty clean? How does its health compare with other estuaries in the United States? Are things getting better or worse? Does costly wastewater treatment have benefits? What are the biggest threats to the Bay and how can we reduce or eliminate those threats? How will the Bay change in the future? These questions can only be answered with investments in study and monitoring, and they are the driving force behind the Regional Monitoring Program (RMP). We describe here some selected results from water quality surveillance conducted by the U.S. Geological Survey (USGS) as one component of the RMP. We present results as lessons about how the Bay works as a complex dynamic system, and we show how these lessons are relevant to the broad RMP objectives supporting Bay protection and management.

The USGS-RMP Water Quality Monitoring Program

The RMP is one of several institutional investments to document and understand the changing condition of San Francisco Bay's living resources and water quality. The California Department of Fish and Game samples fish populations every month, and has maintained this invaluable Baywide monitoring since 1980 as a component of the Interagency Ecological Program <www.iep.water.ca.gov>. USGS scientists have studied physical, chemical, geological, and biological processes in San Francisco Bay since 1969, the longest continuing program of observation and study in a coastal ecosystem in the United States. The RMP filled a key gap when it became the first Baywide program to routinely monitor contaminants in water, sediments, and aquatic organisms, beginning in 1993. At its inception, the RMP established a partnership with USGS as a step toward the RMP objective of developing a complete picture of the sources, distribution, fate, and effects of contaminants in the Bay ecosystem.

The RMP is designed to detect trends of contaminant change over periods of years, but long-term trends can be difficult to identify or understand without knowledge of changes that occur over shorter time periods, within years. The function of USGS water quality monitoring within the RMP is to measure water quality indicators at weekly-to-monthly frequency to document changing Bay conditions over seasonal cycles and during events (floods, algal blooms, storms) that influence contaminant inputs, fate, and effects. This work builds a foundation of knowledge about Bay dynamics required to interpret trends measured in other RMP components. The USGS makes monthly measurements at 38 stations along the 145 km channel from the lower Sacramento River to the lower South Bay (Figure 1). Sampling is also done weekly in South Bay during spring when water quality is highly variable because of phytoplankton blooms. Measurements are made over the entire water depth with sensors for water temperature, salinity, suspended solids, chlorophyll a, and dissolved oxygen. Since 1993, the USGS has conducted 99 full-Bay and 175 South Bay sampling cruises, making over 61,000 measurements of each water quality parameter. Interested parties can download these data for their own analyses <http://sfbay.wr.usgs.gov/access/wqdata>. These data are used beyond the RMP: by marine-science teachers, students from elementary to graduate school, researchers around the world, consulting firms, and other government agencies. What have we learned about the Bay from this monitoring?

Oxygen as an Essential Element

A common impairment of coastal water bodies, such as Chesapeake Bay and the northern Gulf of Mexico, is depletion of dissolved oxygen from bottom waters. Oxygen depletion can kill fish and shellfish and exclude biota from large areas of habitat. Oxygen depletion is caused by microbial communities in water

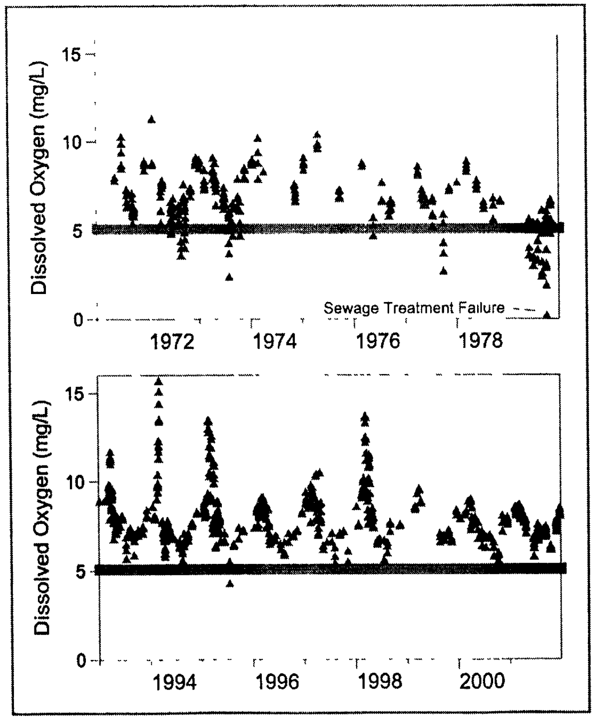


Figure 2. Oxygen conditions in the Bay have improved due to investments in wastewater treatment. Dissolved oxygen (DO) concentrations in San Francisco Bay nearly always exceed the 5 mg/L standard (red bar) protecting sensitive species of fish from oxygen depletion. The top panel shows bottom-water DO in lower South San Francisco Bay (USGS Stations 32-36) during the 1970s when summer DO episodically fell below the standard (note the disappearance of oxygen during the September 1979 disruption of sewage treatment). The bottom panel shows consistently high DO since 1993, reflecting improvements from advanced wastewater treatment that greatly reduced inputs of oxygen-consuming pollutants. San Francisco Bay is no longer impaired by low oxygen conditions.

and sediments as they respire to maintain their metabolism. **Microbial metabolism depends on a** supply of organic matter, and oxygen depletion occurs when the supply of organic matter exceeds the capacity of a water body to replenish oxygen. Organic matter comes either from direct inputs (e.g., of poorly-treated sewage) or from phytoplankton biomass produced from nutrients delivered by surface runoff or wastewater. Data collected by the USGS-RMP monitoring program since 1993 show that San Francisco Bay waters always have sufficient oxygen (> 5 mg/L) to sustain metabolism of the most sensitive fish species (Figure 2).

This was not always the case. In the 1950s and 1960s, before regulation of wastewater inputs by the 1972 Federal Clean Water Act, summer oxygen depletions were common, especially in the lower South Bay, which received large inputs of oxygen-demanding cannery waste and ammonia. Even in the 1970s, data collected by USGS showed episodic depletions of dissolved oxygen below 5 mg/L (Figure 2). The trend of steadily increasing dissolved oxygen and elimination of low-oxygen conditions is a compelling success story of water quality management, an example of benefits derived from investments in advanced wastewater processes that reduce inputs of oxygen-consuming wastes.

Monitoring allows regulators to identify and focus on pollutants posing the greatest threats

The past decade of USGS-RMP data provides strong evidence supporting a regulatory decision to remove San Francisco Bay from the list of California water bodies impaired by low oxygen. This illustrates how monitoring provides a scientific basis for prioritizing management actions so that regulatory efforts can identify and focus on pollutants posing the greatest threats to water quality and human and ecosystem health. Continued vigilance **through monitoring is essential, however, because events remind us that the oxygen content of water can still disappear rapidly** following high organic inputs. In September 1979, the South Bay basin below the Dumbarton Bridge was oxygen-depleted and regions were devoid of fish and shrimp for several weeks (prompting the news headline *Sewage Leaves Bay a 'Dead Sea'*), following inputs of primary-treated sewage during a disruption of the San Jose-Santa Clara Waste Treatment Facility (Cloern and Oremland 1979).

The Bay as an Open Ecosystem

San Francisco Bay is connected to large rivers, urban watersheds, and the coastal Pacific Ocean. The Bay is profoundly influenced by inputs from these three connections, each having its own chemical makeup and distinct variability. Salinity in the Bay is a simple indicator of river-runoff inputs, and salinity measurements before and after the 1997 New Year's Flood showed remarkable changes in the composition of Bay water (Figure 3). Average salinity dropped from 26.1 to 9.0 psu (the salinity of fresh water is 0 psu and the salinity of seawater is 35 psu), so the Bay as a whole changed from 79% seawater to only 27% seawater. Salt dilution of this magnitude shows that more than half the Bay's water volume was displaced by river inflow between November 1996 and January 1997. During these periods of high inflow, concentrations of runoff-derived contaminants (e.g., chromium, nickel) increase, and concentrations of locally-derived industrial contaminants (e.g., silver) decrease in clam tissues (Brown and Luoma 1999; Brown et al. 2003). The availability of some metals (e.g., cadmium) for uptake by aquatic organisms varies with salinity, so salinity monitoring provides essential information for understanding changes in organism contamination.

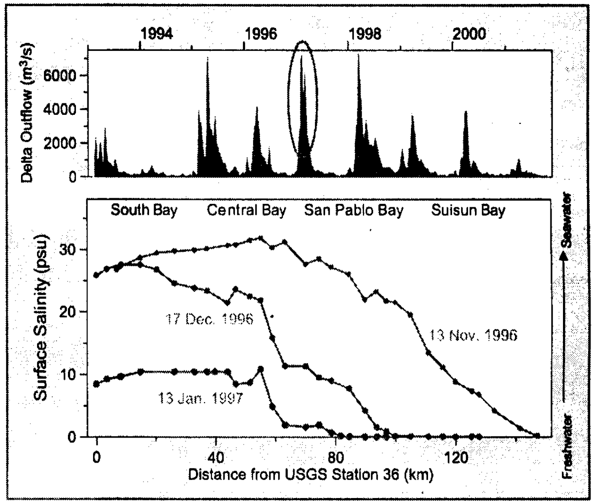


Figure 3. The Bay is profoundly influenced by water inputs from the Delta. Salinity measures the relative proportions of freshwater and seawater in an estuary, a key environmental factor for interpreting changes in the sources, concentrations and biological availability of toxic substances. Winter floods replace brackish Bay water with freshwater, diluting some contaminants (e.g., silver) and delivering others (e.g., mercury, PCBs). The bottom panel shows salinity along the Bay during three sequential USGS monitoring cruises to illustrate Baywide displacements of salt when Delta outflow increased in December 1996 and peaked during the 1997 New Year's flood. The top panel shows 1993-2001 Delta Outflow (California Department of Water Resources), highlighting this flood event. (Delta outflow is plotted as a 7-day average to smooth the large daily variability.)

The Pacific Ocean is another powerful force of change, and we can use other indicators to study the influence of oceanic processes on the living Bay system. In September 2002, patches of colored water were observed in Central Bay; microscopic analyses revealed that the 'red tide' was a bloom of *Heterosigma akashiwo*. This harmful alga has never been reported in the Bay before, and its presence is reason for concern because it is associated with fish kills in Puget Sound and other coastal ecosystems. Causes of the *Heterosigma* bloom in San Francisco Bay are a mystery, but satellite imagery suggests that it originated offshore and propagated into the Bay. A satellite image from SeaWifs (Figure 4) shows an abundance of phytoplankton (chlorophyll a) offshore on September 16, 2002, consistent with reports of red tides off Stinson Beach and Bodega Bay. This image clearly depicts the Bay's ocean connection and the lesson that water quality and living resources inside the Bay are influenced by events outside the Golden Gate, just as they are influenced by inputs from the rivers and urban watersheds. Lessons from monitoring teach that the Bay is an open system that responds to change at its boundaries.

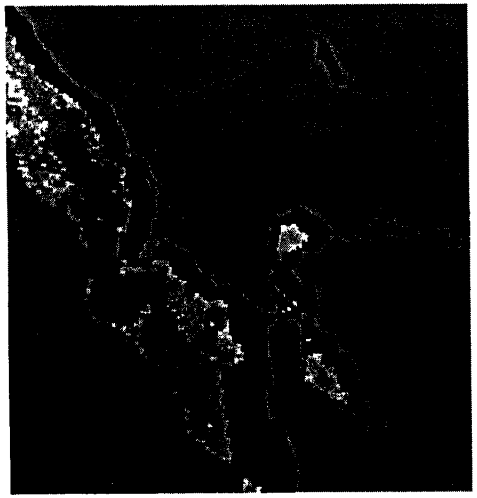


Figure 4. Water quality and living resources inside San Francisco Bay are influenced by events outside the Golden Gate. This satellite (SeaWiFS) image from September 16, 2002 shows high quantities of phytoplankton (microscopic algae) as red in the nearshore Pacific Ocean. At the same time, a red tide bloom of a toxin-producing species of phytoplankton was observed inside San Francisco Bay. [Black indicates no data, typically due to the presence of land or clouds. Color inside San Francisco Bay is not accurate because of interference by suspended sediments.]

Phytoplankton as Food Resource and Contaminant Carrier

The largest living component of San Francisco Bay is invisible to the naked eye – the suspended microalgae, or phytoplankton. Phytoplankton photosynthesis is the most important energy supply to Bay-Delta foodwebs (Jassby et al. 1993; Sobczak et al. 2001), supporting clams, worms, shrimp, zooplankton, herring, sturgeon, striped bass, canvasback ducks, pelicans and, ultimately, harbor seals. Phytoplankton photosynthesis in the Bay produces about 120,000 tons of organic carbon each year, or the number of calories required to sustain over a million adult humans. This food supply is smaller than average for the world's estuaries (partly because the Bay is turbid), and as a result phytoplankton consumers such as zooplankton, mysid shrimp and clams are usually limited by the available supply of food. Food limitation disappears during phytoplankton blooms, when phytoplankton biomass becomes high enough to sustain maximum rates of growth and reproduction by these consumers (Cloern 1996).

Phytoplankton production also transforms dissolved chemicals (carbon dioxide, nitrate, phosphate, trace metals, organic molecules) into particulate forms (algal cells) that can be consumed by organisms at the next trophic level. This transformation is the entry point of contaminants into foodwebs, including priority pollutants such as selenium, mercury, and PCBs that increase to potentially toxic levels as they are transferred up the food chain. Because phytoplankton production and transformation of trace metals accelerate during blooms (Luoma et al. 1998; Beck et al. 2002), these events act as biological regulators of the toxicity and accumulation of contaminants in Bay foodwebs.

Phytoplankton monitoring at weekly-monthly frequencies reveals seasonal patterns such as the prominent spring bloom that occurs every year in South Bay (Figure 5), whereas continuous monitoring with moored instruments enables us to measure short-term variability between ship-based samplings. Sustained monitoring over decades shows that there has been a change in the annual pattern from a spring bloom cycle to a spring and autumn-winter bloom cycle in the South Bay (Figure 5). This recent departure from a 21-year pattern suggests that the South Bay has experienced a regime shift, for reasons not yet identified. Clues might come from a recent study showing multi-decade biological cycles around the Pacific Basin (Chavez et al. 2003). Could the recent appearance of autumn-winter blooms inside San Francisco Bay reflect a Pacific-scale regime shift? Records from a moored fluorometer (Figure 5) show that chlorophyll varies within a day, sometimes over a range comparable to that measured over seasons or decades. This record shows two peaks per day suggesting a tidal process such as oscillation of water masses containing patchy chlorophyll distributions (Jassby et al. 1997). Lessons from phytoplankton monitoring show that San Francisco Bay is a continually-changing and evolving biological system, over periods from hours to decades. An important challenge of monitoring design is to measure and understand variability at all time scales so that trends of long term change can be detected and interpreted with confidence.

Biological Pollution as Damaging as Chemical Pollution

San Francisco Bay's biological communities are a mix of native and alien species, and some habitats are dominated by aliens. Many species were introduced into the Bay long before monitoring began, so we have no knowledge of the Bay's biological community structure, water quality, or ecosystem functions prior to species introductions by humans. Monitoring in recent decades has provided direct measures of the disturbance caused by alien species. A compelling example is the suite of changes in northern San Francisco Bay that followed, almost immediately, invasion by the Asian clam *Potamocorbula amurensis*. Prior to this invasion in 1986, phytoplankton in Suisun Bay accumulated to high levels in summer (Figure 6). These summer blooms did not appear in 1987 and they have been absent since. *Potamocorbula* filter phytoplankton from water, and they are abundant enough to remove algal cells faster than phytoplankton can reproduce in Suisun Bay. As a result, *Potamocorbula* has reduced primary production five-fold (Alpine and Cloern 1992), creating an environment of chronic food limitation for consumers. Populations of the native shrimp, *Neomysis mercedis*, have nearly collapsed in Suisun Bay and one explanation is depletion of the phytoplankton food resource by *Potamocorbula* (Orsi and Mecum 1996). Similar changes occurred in the crustacean zooplankton communities, so the Interagency Ecological Program (IEP) and USGS monitoring have documented the disruption of communities and ecosystem functions caused by this alien species. Analysis by the Regional Water Quality Control Board concludes that "Exotic species are one of the greatest threats to the integrity of the San Francisco Estuary ecosystem, perhaps as great as any pollutant regulated under the Clean Water Act." Monitoring of biota and measurements of ecosystem functions provide a sound scientific basis for inclusion of exotic species on the 303(d) list of pollutants that impair San Francisco Bay (see Inside Back Cover).

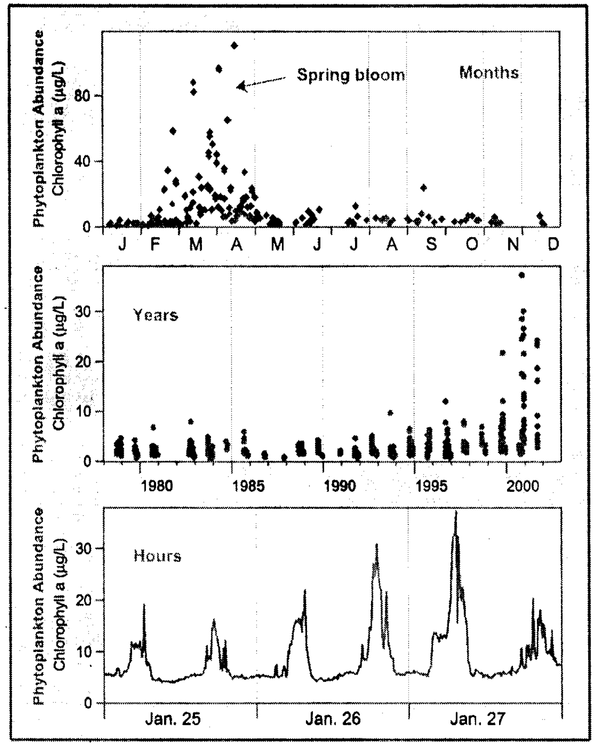


Figure 5. Long-term monitoring has revealed fundamental shifts in seasonal cycles of the Estuary's food supply. Phytoplankton (microscopic, suspended algae) is the largest living component of the San Francisco Bay ecosystem, and phytoplankton photosynthesis is the biological engine that fuels food webs, transforms contaminants, and moves contaminants such as selenium, mercury, and PCBs into food webs. These figures illustrate variability of phytoplankton abundance (as measured by chlorophyll a concentration) at three time scales: the top panel shows monthly variability near the Dumbarton Bridge from 1993-2001, highlighting the spring bloom that typically develops between mid February and mid April. The middle panel shows all measurements made in South San Francisco Bay during September-December from 1978-2002, suggesting a regime shift to autumn-winter blooms beginning in 1999. The bottom panel shows chlorophyll near the Dumbarton Bridge measured every ten minutes during 3 days of January 2003. Comprehensive monitoring documents variability at all these time scales, each of which may be important in understanding water quality in the Bay.

The Need for Comprehensive Monitoring

The lessons described here illustrate how monitoring contributes to resource management. For San Francisco Bay, monitoring data provide the basis for establishing water quality management priorities that have evolved over time and now focus on nonpoint sources of pollution, exotic species, and a prioritized set of toxic contaminants. Monitoring records changes in the chemical and biological condition of San Francisco Bay, providing an objective basis for measuring the benefits of advanced wastewater treatment and point-source reductions of toxic pollutants. It can similarly document responses to future actions such as steps to reduce pollutant loadings from nonpoint sources. Finally, monitoring data provide powerful clues revealing how San Francisco Bay functions as an ecosystem and how its functions respond to both natural forces and human activities.

The need for monitoring information is perpetual because San Francisco Bay will continue to change in ways we cannot predict. We can, however, identify forces of change that might reshape the Bay ecosystem, such as: conversion of salt ponds to new habitats; construction of airport runways; climate changes that alter the seasonal timing and quantity of river runoff; sea level rise; population growth adding over 1.4 million Bay area residents by 2020 <http://www.dof.ca.gov/>; unanticipated introductions of new species; and regulatory actions such as implementation of TMDLs. Although we know with certainty that San Francisco Bay will change in coming decades, there is no institutional framework to fully document, understand and support adaptive management to those changes. The USGS-RMP partnership illustrates how resources of two institutions can be combined to meet some specific monitoring needs, but the full suite of potential partnerships has not been melded into a Baywide comprehensive monitoring program.

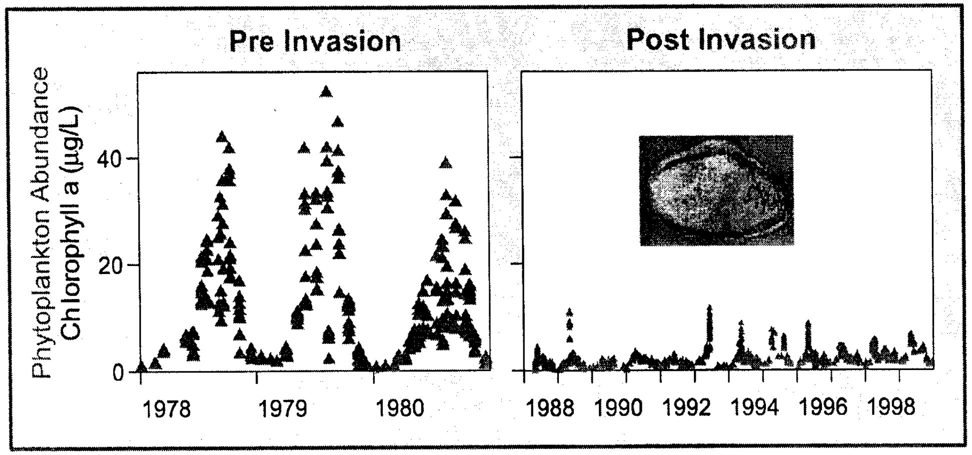


Figure 6. Ecosystem disruption from biological pollution can be as powerful as disruption from chemical pollution. The summer phytoplankton bloom disappeared and abundance and photosynthetic production decreased fivefold in Suisun Bay after invasion by the alien clam *Potamocorbula amurensis* in late 1986. This Figure compares annual cycles of phytoplankton abundance (chlorophyll a) in Suisun Bay for three years before (left panel) and 12 years after this invasion (right panel). The mean pre-invasion (1978-1980) chlorophyll concentration was 9.8 mg/L compared to the mean post-invasion concentration of 2.1 mg/L. Native invertebrates, including important forage species for fish, are now food-limited and populations of some species (the mysid shrimp *Neomysis mercedis*) have virtually collapsed since this invasion.

Our ability to anticipate and document future change in the Bay is deficient in four areas. First, institutional commitments to biological monitoring do not support regular sampling of plankton, sediment-dwelling invertebrates, waterfowl, or mammals. Basic components of water quality such as nutrients, and ecosystem functions such as primary production, are also missing from the existing monitoring effort (IEP monitors nutrients and lower trophic level organisms, but not Baywide). Second, there is no mechanism for integrating and synthesizing information collected by agencies conducting specialized monitoring or research. Data are archived in disconnected databases, and cross-program data synthesis and integration are not supported institutionally. These deficiencies limit our progress toward an ecosystem-scale perspective of the Bay's systemic responses to changes in land use, habitats, waste loadings, climate, and invasive species. Third, existing programs do not fully exploit new technologies such as remote sensing and real-time data collection with moored instruments to measure changes at the spatial and temporal scales missed by ship-based sampling. Finally, institutional commitments have not been made to design, implement and permanently fund a comprehensive monitoring assessment and research program (CMARP), although the need is widely recognized and a general roadmap has been produced <http://www.iep.water.ca.gov/cmarp/>.

Given the value of monitoring to resource management and the certainty of forces that will change San Francisco Bay in uncertain ways, we wonder: How might the monitoring lessons described here be applied to stimulate implementation of a CMARP?

Sediment Dynamics Drive Contaminant Dynamics

David H. Schoellhamer (dschoell@usgs.gov), Gregory G. Shellenbarger, and Neil K. Ganju – U.S. Geological Survey, Menlo Park, CA
Jay A. Davis, and Lester J. McKee – San Francisco Estuary Institute, Oakland, CA

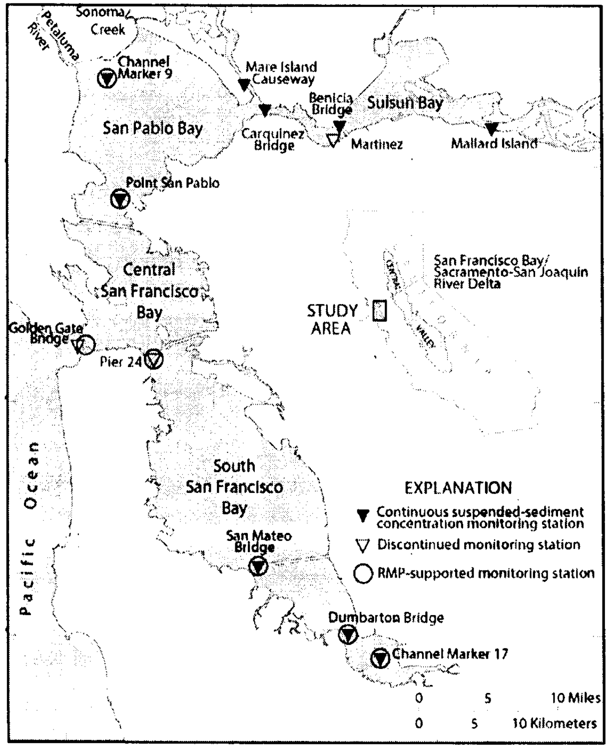


Figure 1. Suspended sediment concentration monitoring stations in San Francisco Bay. Monitoring stations have been established in each major region of the Bay. Funding for this network is provided by RMP, USGS, and many other entities.

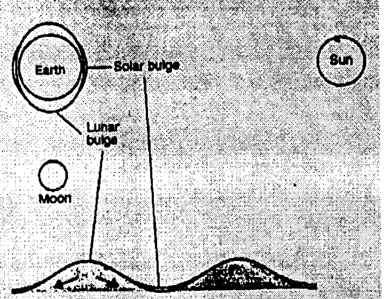
INTRODUCTION

Many contaminants of greatest concern in San Francisco Bay, including mercury and PCBs, are primarily associated with sediment particles rather than dissolved in water. Therefore, the movement and fate of sediment determines the movement and fate of many contaminants in the Bay. Because of this close association, the RMP monitors and seeks to understand the quantity and movement of sediment suspended in the water. Through study of suspended sediment dynamics, the RMP is developing a better understanding of trends and patterns of contaminants and how the Bay will respond to management actions during the next several decades. Recent RMP efforts to develop predictive models of contaminant fate in the Bay have highlighted the fundamental importance of understanding sediment dynamics.

Sediment movement in the Bay is determined by tides, wind, and freshwater inflow. Tides flood and ebb twice a day, wind typically is strongest in the afternoon, and freshwater inflow is greatest during the winter rainy season (see sidebar on next page). To characterize these fluctuations, the U.S. Geological Survey (USGS) began continuous monitoring of suspended sediment concentration in 1991. Continuous suspended sediment concentration monitoring stations were established in each major region of San Francisco Bay (Figure 1), establishing a continuous monitoring network. The sensors at each station measure the amount of material in the water every 15 minutes. Results are available on the internet at <http://sfports.wr.usgs.gov/Fixed_sta/>. In addition to the network, sensors have been deployed at as many as 14 additional sites in the Bay for periods of several months as part of focused studies of sediment transport in Bay locales of special interest.

MANY PRIORITY CONTAMINANTS ARE CLOSELY ASSOCIATED WITH SEDIMENT PARTICLES

Sediment becomes suspended in the water column through a variety of physical processes and transports associated contaminants around the Bay. For example, mercury is a contami-



The gravitational pull of the sun and moon generates tides with flood (landward) and ebb (seaward) currents. The rotation of the earth and moon create in San Francisco Bay two flood and ebb tides every 24.8 hours. Tidal currents are strongest during full and new moons, called spring tides, and weakest during half moons, called neap tides. As a result, suspended sediment concentrations are larger during spring tides than during neap tides (Figure 3).

nant of concern because of its toxicity and tendency to bioaccumulate in the food web. The vast majority of mercury in the Bay is a legacy of mercury mines in the Bay Area, especially in the Guadalupe River watershed in South Bay, and from hydraulic mining for gold in the Sierra Nevada. Because mercury samples are expensive to collect and analyze, it is desirable to find a proxy that can be sampled easily and inexpensively. Suspended sediment fills this role. RMP data collected from 1993-2000 at five sites in San Pablo Bay show that mercury concentrations were closely related to suspended sediment concentration (Figure 2). Ninety-one percent of the variation in the mercury concentration can be explained by variation in suspended sediment concentration.

Using this linear relation, continuous total mercury concentration can be estimated from continuous suspended sediment concentration data. Figure 3 shows the suspended sediment and estimated total mercury concentrations at Point San Pablo during water year 2000. The record is highly variable through the year, reflecting physical processes such as the spring-neap and diurnal tidal cycles, rainfall and runoff and associated variance in concentrations and loads, and wind-wave resuspension of bottom sediment. The strongest signals are caused by increased sediment supply during the rainy season (October through April) and resuspension and transport of bottom sediments during energetic spring tides.

Water Quality Objective for Mercury Exceeded When Suspended Sediment Concentration is Large

The San Francisco Bay Regional Water Quality Control Board has set a water quality objective for total mercury concentration of 25 ng/L averaged over any four-day period. A time series of the estimated mercury concentration can be used to evaluate how often that objective was met from

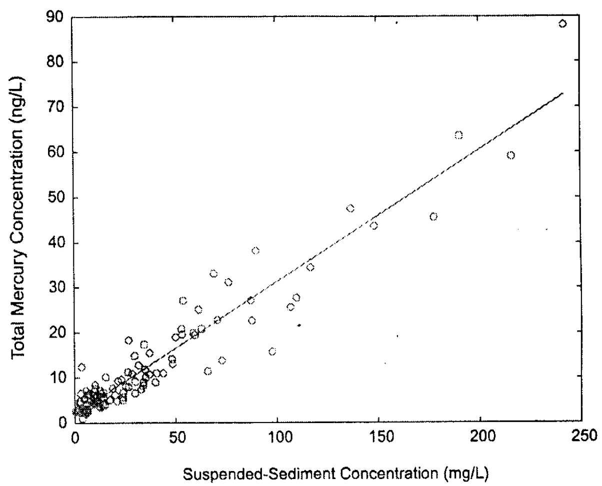


Figure 2. Many priority contaminants are closely associated with sediment particles. This Figure shows the close relationship between mercury and suspended sediment in RMP samples from San Pablo Bay, 1993-2000. Because of this close relationship, suspended sediment monitoring can provide insights into the behavior of mercury in the Estuary.

1993-2000 (Figure 4). The objective was exceeded about 25% of the time.

Compliance with the water quality objective depends on the amount of suspended sediment, which, in turn, depends on the motion of Bay water. Faster water applies more force to the bottom of the Bay, resuspends bottom sediment, increases suspended sediment concentration, and can increase total mercury concentration above the water quality objective. The motions of the earth and moon create tidal cycles and periods of faster water. Semimonthly (spring tides), monthly, semiannual tidal cycles, and the strongest winds in spring and summer that generate the largest waves, account for most of the variability in Figure 4 and determine whether the water quality objective is met (Schoellhamer 2002).

Sediment Transport Explains Contaminant Distribution: Petaluma River

The RMP consistently has measured high concentrations of contaminants in the mouth of the Petaluma River, which drains into northern San Pablo Bay (RMP 2002). Sediment transport between the Petaluma River and San Pablo Bay creates high suspended sediment concentrations, which largely explains the area's high concentrations of contaminants.

The USGS and the University of California at Davis collected continuous hydrodynamic and suspended sediment concentration data in the Petaluma River from January 1999–August 1999, and from September 2000–March 2001 (Barad et al. 2001). These data complemented those from the RMP/USGS continuous suspended sediment concentration station in northwest San Pablo Bay, at Channel Marker 9 (Figure 1) (Ganju et al., written commun., 2003). The geometry and tidal currents in the area create a process of sediment erosion and deposition that repeats with each tidal cycle (about every 12.4 hours). As water flows seaward on ebb tides, the tidal currents apply force to the river bed. An upstream deposit of sediment on the bed of the Petaluma River is eroded and mixed into the water column (Figure 5). As this suspended sediment mass moves downstream, very high suspended sediment concentration are present (>500 mg/L). Once the suspended sediment mass reaches San Pablo Bay, the slack tide and broad area allow sediment to drop out of the water, forming a downstream sediment deposit. As water begins flowing landward immediately after the tide turns from slack to flood, the down-

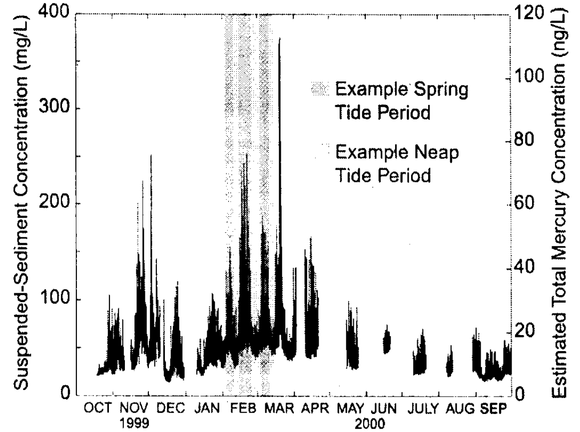


Figure 3. Suspended sediment concentrations in the Bay are highly variable, driven primarily by tides, wind, and freshwater inflow. Suspended sediment concentration (left axis) and estimated total mercury concentration (right axis) at Point San Pablo during water year 2000. Concentrations are highly variable through the year, reflecting physical processes such as the spring-neap and diurnal tidal cycles, rainfall and runoff, and wind-wave resuspension of bottom sediment. The highest concentrations are caused by increased sediment supply during the rainy season (October through April) and resuspension and transport of bottom sediments during energetic spring tides.

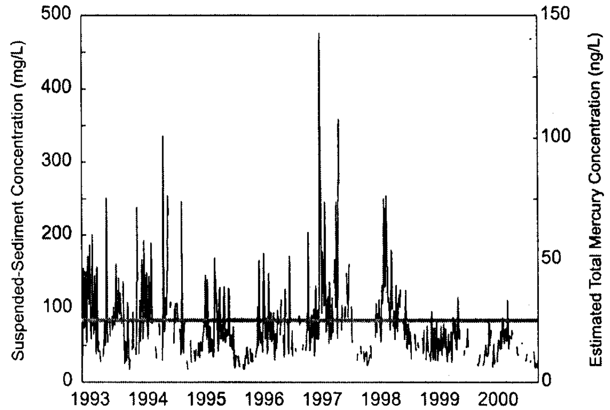


Figure 4. Fluctuations in suspended sediment concentrations drive fluctuations in concentrations of contaminants in Bay water. The water quality objective for mercury concentration is 25 ng/L averaged over any four-day period (horizontal line on graph). This figure shows four-day average suspended sediment and estimated total mercury concentrations at Point San Pablo for direct comparison to the water quality objective. Much of the variation observed can be attributed to the processes described in Figure 3. Another important factor is the trend toward declining sediment loads to the Estuary, especially apparent in the dry years of 1999 and 2000. With less sediment entering the Bay, there was less sediment that could be mobilized by tides and wind, suspended sediment concentrations were lower, and the water quality objective was met during all but the strongest spring tides. Continued declines in sediment load to the Estuary could lead to fewer and fewer exceedances of the mercury water quality objective.

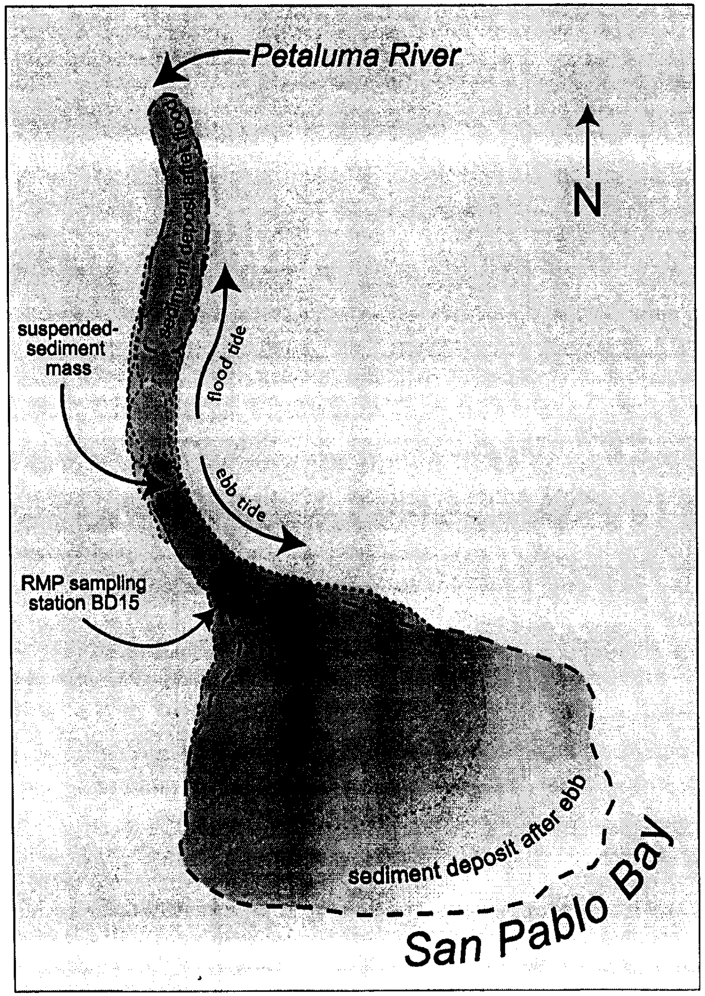


Figure 5. Sediment dynamics explain spatial patterns in contaminant concentrations. The RMP consistently has measured high concentrations of suspended sediment and contaminants in the mouth of the Petaluma River, which drains into northern San Pablo Bay. Sediment transport studies have shown that these high concentrations are due to the oscillation of a cloud of sediment back and forth between San Pablo Bay and the Petaluma River. Sediment deposits at slack tides, and is in motion during flood and ebb tides.

stream sediment deposit is re-suspended and transported upstream. This to and fro process then repeats, with the same sediment mass oscillating back and forth between the Petaluma River and San Pablo Bay. Sediment effectively is trapped within this area, except during large flows in the Petaluma River. This process accounts for the high concentrations of suspended sediment concentration and contaminants in RMP samples collected at the mouth of the Petaluma River. Similar conditions were observed at the mouth of Sonoma Creek.

Sediment and Contaminant Loads from the Central Valley

California's Central Valley historically is the dominant source of runoff and sediment to San Francisco Bay, and it continues to be an important source of contaminants. Hydraulic gold mining in the Sierra Nevada from 1852–1884 utilized and discharged mercury and enhanced the supply of sediment to Central Valley rivers, subsequently causing an increase in sediment and mercury loads from the Valley into the Bay (Figure 6). During the 20th century, watershed runoff delivered contaminants from agricultural and industrial development to the Estuary. For most contaminants, the largest source has been the Central Valley (Davis et al. 1999, 2000). Future population growth is expected to be greater in the Central Valley than in the San Francisco Bay Area, which may increase the Central Valley's importance as a source of contaminants to the Estuary.

In a RMP study, the USGS and SFEI are collaborating to quantify sediment and contaminant loads from the Central Valley to San Francisco Bay. Tides, large channel cross sections, and episodic flood pulses complicate load estimation. McKee et al. (2002) combined USGS continuous suspended sediment concentration data and California Department of Water Resources (DWR) outflow data at Mallard

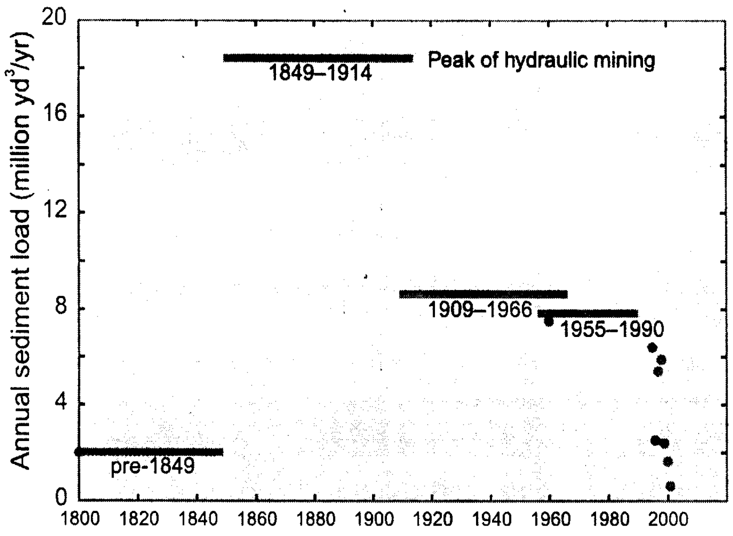


Figure 6. Sediment supply to the Estuary has declined in recent years, making sediment a scarce resource and possibly exacerbating water quality problems. Estimated sediment inputs to the San Francisco Estuary (Gilbert 1917, Krone 1979, Porterfield 1980, Ogden Beeman, and Associates 1992, McKee et al. 2002). Bars indicate estimates over entire period and points indicate yearly estimates. Hydraulic gold mining in the Sierra Nevada in the late 1800s greatly increased sediment loads over pre-1849 levels. Loads declined in the 1900s due primarily to the establishment of reservoirs on tributaries throughout the Estuary watershed. At present, the diminishing supply of sediment threatens to exacerbate existing water quality problems by increasing erosion of sediment from the Bay floor.

Island to estimate sediment loads into the Bay. They determined an average load of 5.2 ± 0.9 million yd^3 per year from 1995 to 1998. Additional sediment data have been collected since 1998 (Buchanan and Ruhl 2001, Buchanan and Ganju 2002). Using the same methods as described by McKee et al. (2002), the estimated average annual sediment load from 1995-2001 (7 years) was 3.6 ± 0.6 million yd^3 per year, down from the hydraulic mining peak of 18.4 million yd^3 per year between 1849-1914 (Gilbert 1917). This decrease in sediment load (Figure 6) is consistent with decreasing sediment load from 1957-2001 in the lower Sacramento River (Wright and Schoellhamer 2003). In a followup to the McKee et al. (2002) study, the RMP is characterizing contamination of suspended sediment entering the Bay to develop improved estimates of contaminant loads from the Central Valley.

Sediment load affects water quality in the Bay. The smaller sediment load from the Central Valley in 1999 and 2000 (Figure 6) probably explains the smaller suspended sediment concentration and increased compliance with the mercury water quality objective at Point San Pablo (Figure 4). With less sediment entering the Bay, there was less sediment that could be mobilized by tides and wind, suspended sediment concentration was less, and the water quality objective was met during all but the strongest spring tides.

It is difficult to predict the long-term effect of reduced sediment load on Bay contamination. On one hand, reduced sediment load from the Central Valley can be expected to reduce concentrations of mercury suspended in water. On the other hand, however, another expected effect of reduced sediment load to the Bay is increased erosion of bed sediment on a regional scale (Jaffe et al. 1999). Erosion of buried sediment, which was deposited in past decades with higher contaminant loads, reintroduces relatively contaminated sediments into circulation in the Bay (Marvin-DiPasquale et al. 2003).

Sediment and Contaminant Budgets

The bed sediment in San Francisco Bay is a major repository and source of many contaminants. For example, PCBs are legacy contaminants that no longer are manufactured but persist in the bed sediment and pose a human health risk because of their accumulation in Bay sport fish. The USGS and RMP are developing a sediment budget and a numerical model to better understand the long-term (decadal) sedimentation of the Bay and associated contaminant fate. These tools will provide an essential foundation for predicting long-term trends in concentrations of persistent contaminants, thus helping improve the development of TMDLs for the Bay.

A financial budget is useful for evaluating income, expenses, and gain or loss of savings. Similarly, a sediment budget is useful for evaluating sediment sources, sediment sinks, and erosion or deposition in the Bay. For contaminants associated with sediment,

Mercury (Hg)

Mercury is naturally abundant in the rocks of the Coast Range of northern and central California. Human activities over the past 150 years have moved a substantial amount of this mercury out of the rocks and into the ecosystem.

Mercury has numerous commercial and industrial uses, including thermometers, fluorescent lamps, dental fillings, and batteries. During the late 1800s and early 1900s, mercury was mined intensively in the California Coast Range for use primarily in gold extraction in the Sierra Nevada. Although the extraction of gold by mercury amalgamation has been banned in the United States, San Francisco Bay continues to receive mercury from mine drainage and mining debris deposits in upland watersheds (SFEI 1999a).

Mercury is found in several forms, some of which have much greater potential for harm than others. Methylmercury (CH_3Hg^+) is the form of greatest concern since it accumulates in animal tissue and moves from prey to predator up the food web. Methylmercury is produced by bacterial action in sediment.

Mercury is of high concern with regard to human health since it accumulates in tissues, and its levels increase up the food web. Human exposure to mercury occurs primarily through consumption of contaminated fish. Mercury is a neurotoxicant and is particularly hazardous to the developing nervous system of fetuses and children.

Mercury also has potential to harm the ecosystem, especially birds and other wildlife high in the food web.

development of a sediment budget is needed to develop a contaminant budget. The most recently published sediment budget for San Francisco Bay was written by Ogden Beeman and Associates (1992). Sediment supply and dredging volumes have decreased since, and large wetland restoration projects and airport runway expansion projects that would create new sediment sinks have been proposed. The USGS is using new suspended sediment concentration data, interpretive studies, and numerical models to update the sediment budget for San Francisco Bay.

A simple numerical model can be used to provide a sediment or contaminant budget that varies over decades. Davis (2003) developed a numerical model of the long-term fate of PCBs in San Francisco Bay that represented the Bay as one well-mixed box. A one box model, however, blurs over the different long term deposition and erosion patterns known to exist in different parts of the Bay (Jaffe et al. 1999). The USGS is collaborating with SFEI to develop a multi-box model for PCB cycling in San Francisco Bay. The wealth of suspended sediment concentration and bathymetric data available in San Francisco Bay will be used to improve the reliability of the model.

Science to Better Manage the Bay

The data and findings from the RMP and USGS sedimentation studies not only benefit the RMP but also benefit restoration projects, construction projects, such as the proposed San Francisco Airport runway expansion, and other scientific studies. Data from these studies are published (Buchanan and Ganju 2002) and available on the internet <http://sfports.wr.usgs.gov/Fixed_sta/>, and significant findings are published in peer-reviewed journals (see the bibliography at <http://ca.water.usgs.gov/abstract/sfbay/sfbaycontbib.html>).

RMP and USGS sedimentation studies provide scientific and programmatic integration that benefit Bay science and management. Sedimentation studies integrate the scientific disciplines of physics, chemistry, and ecology because sedimentation is controlled by physics and affects the chemistry and ecology of the Bay. The collaboration of the USGS and RMP strengthens both organizations and improves the greater understanding of the Bay. The RMP also benefits from the contributions from other agencies and programs to Bay sedimentation studies. In addition to RMP support received from the San Francisco District of the U.S. Army Corps of Engineers, support for the data and analyses presented in this article came from the California Department of Fish and Game, California Department of Transportation, California Coastal Conservancy, CALFED Bay/Delta Program, San Francisco Bay Regional Water Quality Control Board, U.S. Environmental Protection Agency CISNet Program, U.S. Fish and Wildlife Service Coastal Program, and USGS Place-based and Federal/State Cooperative Programs. In addition, the Interagency Ecological Program supports continuous salinity monitoring stations that are co-located with some RMP sediment monitoring stations, thus reducing the costs to both Programs.

For several reasons, appreciation of the importance of sediment dynamics in the Bay has grown markedly in recent years. First, as discussed in this article, the long-term data set is beginning to yield valuable insights, such as the effect of reduced sediment supply on compliance with water quality objectives. Second, sediment dynamics explains the spatial and temporal variability of some contaminants, such as mercury and PCBs. Third, the development of mass budgets and predictive models has enhanced our understanding of the influence of sediment dynamics on long-term trends in contaminant concentrations. Fourth, massive development and restoration projects (the San Francisco airport extension, CALFED restoration projects, restoration of the South Bay salt ponds) that could have a huge effect on the Bay's sediment budget currently are being evaluated. Continued monitoring and analysis of sediment dynamics is essential to understanding the effects of management actions on water quality and the ecology of San Francisco Bay.

Ten Years of Testing for the Effects of Estuary Contamination

Brian Anderson (anderson@ucdavis.edu) – U.C. Davis, Davis, CA • Scott Ogle – Pacific EcoRisk, Martinez, CA
Sarah Lowe – San Francisco Estuary Institute, Oakland, CA

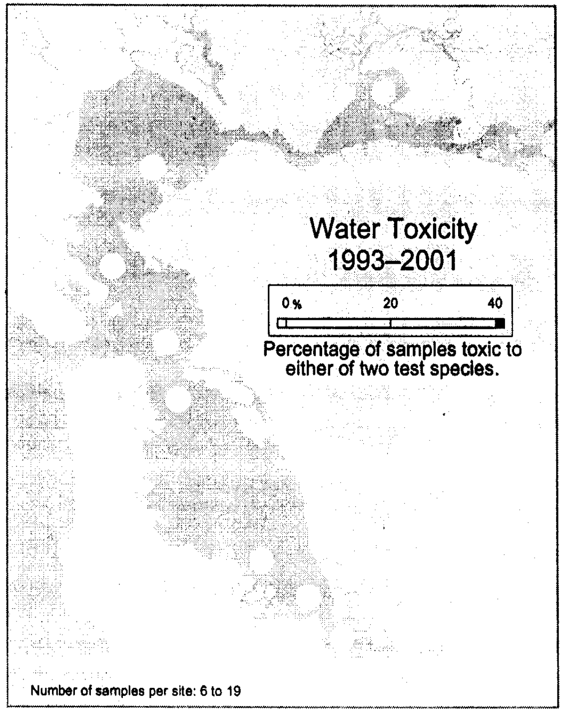


Figure 1. Toxic water in the Estuary has been observed less frequently in recent years. From 1993 to 2001, 13% of water toxicity samples collected by the RMP Status and Trends component were toxic to one or more test organisms in the laboratory (mysid shrimp or bivalve larvae). Most of this toxicity was observed in wet season samples and occurred in the northern and southern reaches of the Estuary. From 1998, only two sites in the southern sloughs of the Estuary have been toxic.

INTRODUCTION

Complex mixtures of contaminants are found in the Estuary and their effects on aquatic life are difficult to evaluate. Knowing the individual concentrations of chemicals is not enough to determine if estuarine waters will be harmful to resident species. Toxicity tests are laboratory procedures designed to determine whether chemical levels in water or sediment samples from the Estuary might impact aquatic life. Water quality objectives adopted by the Regional Water Quality Control Board are established to comply with Clean Water Act provisions that prohibit the presence of contaminants in toxic amounts (Basin Plan, 1995). Toxicity tests are used to monitor compliance with these objectives. Combined with chemical measurements (in water, sediment, and tissue), biological community characterizations, measures of other factors that may affect aquatic organisms, and studies of effects on populations of aquatic organisms, laboratory toxicity tests add to the group of measurements used to assess the health of the estuarine ecosystem.

Toxicity testing has been included in the RMP since the Program began in 1993. This element of the RMP has been continually adjusted and improved providing an excellent example of adaptive program management. This element appears to have documented the reduction of aquatic toxicity in the Estuary in response to declining use of organophosphate (OP) pesticides.

Contaminants enter the Estuary through a number of pathways, and can be dissolved in water or bound to sediment particles. Water and sediment toxicity are tested separately: water toxicity testing monitors possible effects of chemicals on organisms that live in the water column, and sediment toxicity testing assesses possible impacts on the Estuary's benthos (sediment dwellers). For the RMP, water toxicity is monitored using mysid shrimp and larval fish. Mysid shrimp represent a class of organisms that are important food for fish in the Estuary, and the species being used by the RMP is among the most sensitive test species for water, especially to pesticides and petroleum-related contaminants. Toxicity of sediment contaminants is monitored using mussel embryos and shrimp-like organisms called amphipods. Both tests are considered sensitive indicators of benthic community health.

Aquatic Toxicity in the Estuary

Since 1993, 13% of the water toxicity samples tested by the Status and Trends component of the RMP were found to be toxic to at least one test species. Most of those occurrences happened between 1995 and 1997 in the northern and southern reaches of the Estuary (Figure 1) during the wet season. Since 1998, only two southern slough sites (C-3-0 and C-1-3) showed toxicity (four out of sixteen samples from those sites).

This wet season aquatic toxicity observed in the northern and southern Estuary is suggestive of adverse effects on aquatic invertebrates and the estuarine food web. Long-term studies have reported declines in zooplankton abundance in the Estuary, with recent zooplankton densities from one-tenth to one one-hundredth of those in the early 1970s (Obrebski et al. 1992). While there are other factors that may be driving the zooplankton decline, such as the introduction of the Asiatic clam *Potamocorbula amurensis* (a highly efficient filter feeder) in 1986 (Thompson 1999; Lucas et al. 1999; Parchaso and Thompson 2002), water diversions upstream, and altered food web predation patterns, the use of pesticides has increased substantially over this same period of time, suggesting that contaminants may be contributing to the zooplankton declines (see *Changes in Pesticide Use* below). .

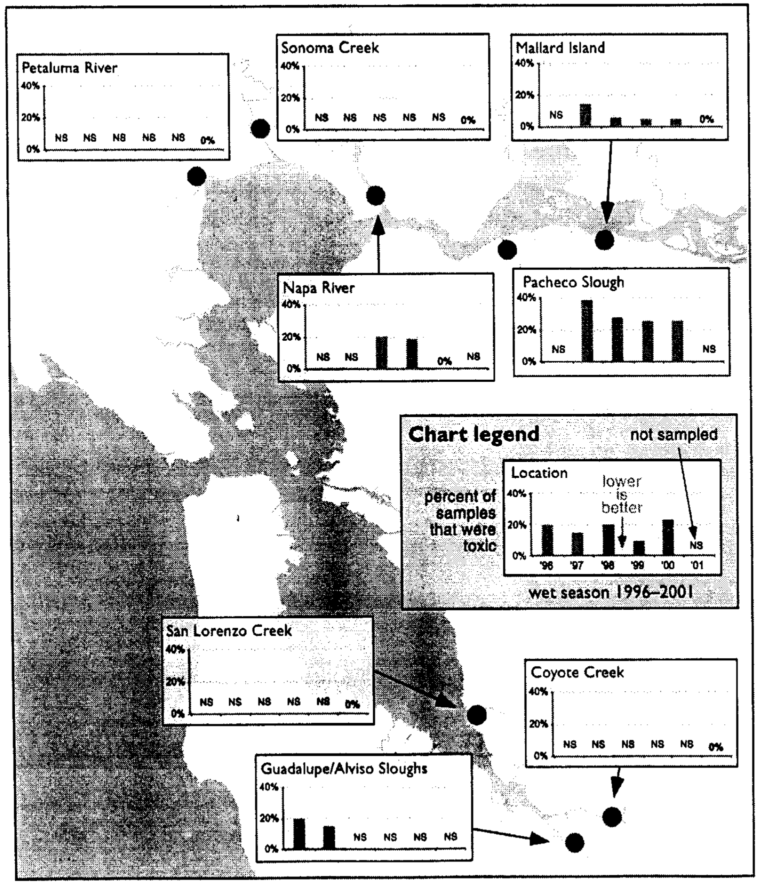


Figure 2. Toxic water samples from Estuary tributaries have also been observed less frequently in recent years. The RMP's Episodic Aquatic Toxicity Study has been sampling toxicity to mysid shrimp and larval fish in tributaries around the Estuary since 1996. During this period, the frequency of observed aquatic toxicity in the tributaries has been decreasing, possibly as a result of a shift in the kinds of pesticides used in the surrounding watersheds.

Based upon the wet season toxicity observed in the Status and Trends monitoring, the RMP initiated a Pilot Study in the winter of 1996 to test the hypothesis that stormwater runoff and other surface water runoff events were the primary sources of episodic water toxicity in the Estuary. The Pilot Study sampled stormwater runoff events at Mallard Island (near the confluence of the Sacramento and San Joaquin Rivers), and in several smaller tributaries throughout the Estuary (see Figure 2).

Is the Water Toxic in the Tributaries?

While most of the water samples tested by the RMP in the Estuary have not been toxic, stormwater samples collected from tributaries and in the northern Estuary following significant rainfall events in 1996 and 1997 were toxic (Figure 2). During two periods in 1998, three consecutive samples taken at two to three day intervals in the northern Estuary were all toxic, suggesting that extended periods of toxicity may occur. Studies on the Sacramento and San Joaquin rivers during this time period found that water in some sections of those rivers were frequently toxic, and OP pesticides (e.g., diazinon and chlorpyrifos) were believed to have been responsible for much of the toxicity (Foe 1995, Ogle et al. 1998). Other studies found that many samples of stormwater runoff from urbanized creeks in the Estuary were also toxic (S.R. Hansen and Associates 1995, Katznelson and Mumley 1997).

In recent years, the frequency of observed wet season aquatic toxicity has declined, and has coincided with the reduction in use of OP pesticides. In 2000, the U.S. EPA acted to reduce the use of two key OP pesticides, chlorpyrifos and diazinon, by phasing out their use in home and garden applications and restricting their use in agriculture. Local agencies around the Estuary are also engaged in public information efforts to reduce the use and improper disposal of OP pesticides by homeowners and businesses. Meanwhile, the urban and agricultural pesticide markets are turning to various alternatives to diazinon and chlorpyrifos, such as pyrethroid insecticides (see sidebar, page 31).

Stormwater toxicity monitoring continues to be conducted by the RMP. Recently, the frequency of toxicity has decreased, most notably at Mallard Island, where none of the 53 samples collected during the wet season of 2001–2002 were toxic (Figure 2). There has also been a marked decrease in the magnitude of the toxicity. Many of the toxic samples collected in the first three years of the Pilot Study caused >50% mortality of test organisms, with several causing 100% mortality. Of the wet season 1999-2000 samples collected, only one resulted in >50% mortality, and none of the samples collected in 2000-2001 resulted in >25% mortality.

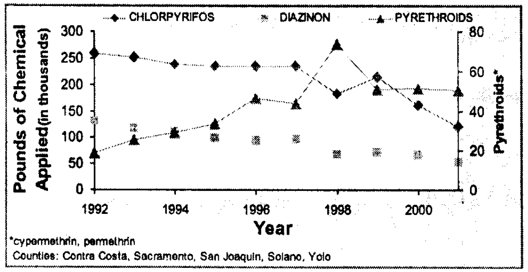


Figure 3. Recent changes in pesticide use may account for the observed decrease in aquatic toxicity in local tributaries of the Estuary. With regulatory measures (in 2000) to reduce the use of OP pesticides such as chlorpyrifos and diazinon in agriculture and homes and gardens, the use of pyrethroid insecticides is expected to increase. This graph shows the pounds of pesticides (in thousands of pounds) applied annually in nearby counties, 1992 – 1998.
Data source: CA Department of Pesticide Regulation http://calpip.cdpr.ca.gov/cfdocs/calpip/prod/main.cfm

Changes in Pesticide Use

Apparent reductions in the magnitude and frequency of ambient water toxicity to the mysid shrimp over the past several years has coincided with recent reductions in the application of OP pesticides in the Estuary's watersheds (Figure 3). While reduced OP applications appear to have remedied the mysid toxicity problem in the Estuary, other pesticides that may pose

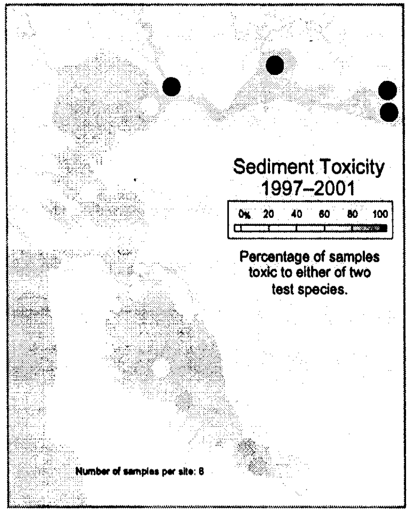


Figure 4. The frequent occurrence of toxic sediment samples in the Estuary is a major concern. From 1997 to 2001, 63% of sediment toxicity samples collected by the RMP Status and Trends component were toxic to one or more test organisms in the laboratory. Sediment toxicity is persistent in the Estuary and more frequent in the northern and southern reaches and near the mouths of small tributaries.

Toxicity Testing

Using contaminant concentrations to predict harm to estuarine life is difficult, as a contaminant's potential for harm is affected by its context in the estuarine environment. Other contaminant levels, salinity, temperature, and many other variables may influence a contaminant's effect.

A more direct approach to assessing potential harm, which avoids many of the difficulties of interpreting contaminant concentrations, is to expose organisms (such as mussels or shrimp) to Estuary water or sediment in the laboratory and look for adverse effects such as developmental abnormalities or death. If a clear adverse effect is seen, it is considered an indication that harm is occurring in the Estuary itself. The ecological relevance of laboratory tests is a matter of some debate, as some of the species used in RMP tests do not actually reside in the Estuary. The RMP is considering increasing its use of resident species to address this issue.

Toxicity tests give no indication of what in the sample is responsible for the observed toxicity. Additional tests, known as toxicity identification evaluations (TIEs) attempt to identify the toxic agent(s). In TIEs, toxic samples are treated to remove a particular type of chemical, and toxicity tests are rerun to see if the toxicity has been eliminated. In this way, indirect identifications can be made. When contaminant mixtures are present, conclusive identification of what is causing the toxicity is often not possible. The RMP plans to increase the use of TIEs on water and sediment samples.

For information on the specific toxicity tests used by the RMP, see the RMP Annual Monitoring Summary reports at <www.sfei.org>.

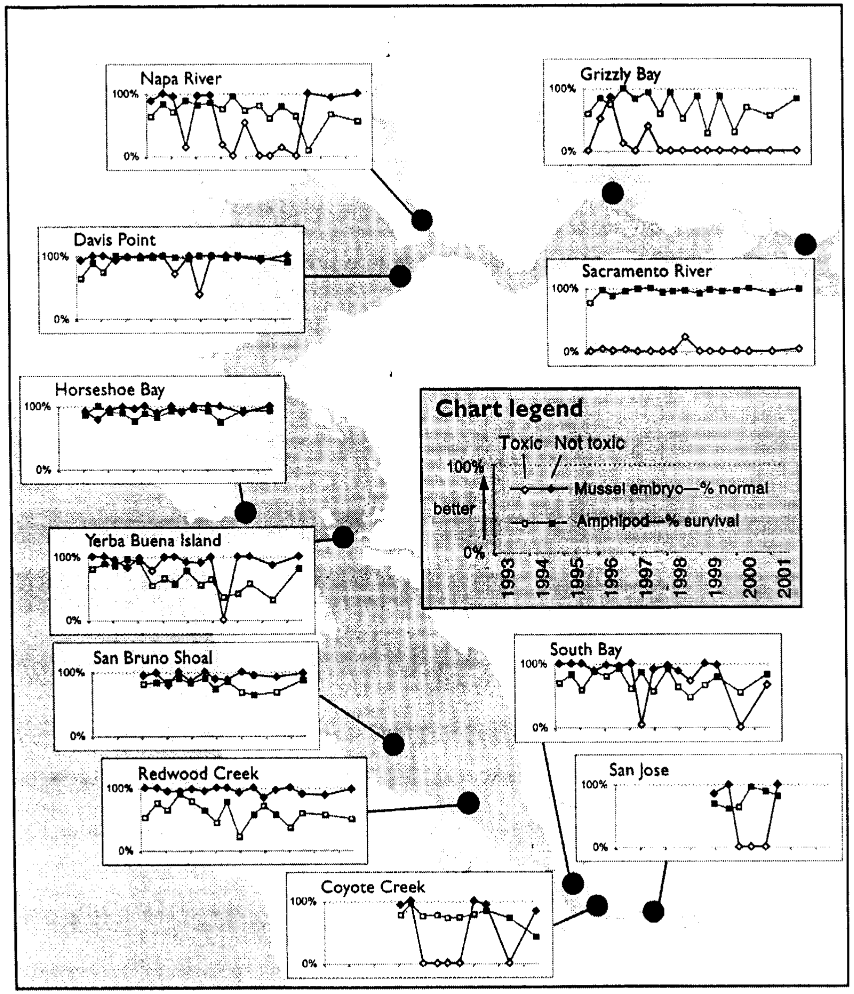


Figure 5. Sediment toxicity in the Estuary is persistent, shows seasonal and regional patterns, and is manifested differently in two laboratory test species. There is more frequent toxicity during the wet season than the dry season, particularly to amphipods. The mussels tend to have a pronounced all-or-nothing response. Samples are persistently toxic to mussels at the Rivers stations and periodically at the South Bay stations.

new problems are being substituted for OP pesticides. For example, the use of alternatives such as pyrethroid insecticides (see sidebar, page 31) has increased over the past few years. Pyrethroids have different properties than OP pesticides, with a greater tendency to adsorb to sediment and greater toxicity to fish. Therefore corresponding changes in the toxicity monitoring approach may be needed (i.e., using tests and test species that will be more sensitive to changing use patterns of pesticides and their fate and transport characteristics). It is critical that the RMP remains vigilant of changes in pesticide use within the Estuary's watersheds and continues to adapt the monitoring approach in response to those changes.

Sediment Toxicity

Toxic sediment is found regularly at a number of sites throughout the Estuary. During the last five years, 63% of the sediment samples tested were toxic to at least one test organism (Figure 4). Since 1993, the RMP has seasonally evaluated the toxicity of sediments to mussel embryos and amphipods. For each seasonal sampling period since 1993, the proportion of sediment samples that were toxic to at least one test organism ranged from 33% to 100%, with no clear overall trend, but with clear seasonal differences (see Figure 5).

As with water toxicity, sediment toxicity is more frequent in the Estuary during the wet season than in the dry season, suggesting stormwater is an important source of contamination that may cause sediment toxicity. This pattern is particularly clear for amphipods. For example, 51% percent of the winter samples tested between 1993 and 1999 were toxic to amphipods, while only 16% of the summer samples were toxic during this period. [Since 2000, the RMP has shifted to dry season toxicity monitoring as part of the redesign of the Status and Trends component of the RMP (*RMP News, Vol 6:2*).]

Sediment from certain stations in the Estuary has been consistently toxic to amphipods and mussel embryos (Figure 5). Samples from Grizzly Bay, the mouth of the Napa River, Redwood Creek, and the

South Bay have usually been toxic to amphipods. Samples from these and other stations have also been toxic to mussel embryos. All samples collected in the northern Estuary (Grizzly Bay and the Sacramento and San Joaquin Rivers) have been toxic to mussels since 1994.

As suggested before, the magnitude of toxicity (the number of dead or poorly developed animals) has been greater in samples collected during the winter months. Analyses to identify the cause of the sediment toxicity have yielded a variety of answers, probably in part due to the complex mixtures of chemicals involved. Comparisons of the chemical data to toxicity test data indicated that amphipod mortality correlated with mixtures of chemicals in sediments, as well as to specific metals and pesticides (Thompson et al. 1999; Anderson et al. 2000; Phillips et al. 2000). Causes of toxicity to mussel embryos were less apparent.

Causes of sediment toxicity have been further investigated using toxicity identification evaluations (TIEs). TIEs are laboratory procedures designed to first characterize the class of chemicals causing toxicity, then identify and confirm specific chemicals responsible for toxicity. TIE procedures developed by the U.S. EPA and novel techniques developed as part of RMP special studies have shown that copper was the likely cause of inhibited bivalve embryo development in sediment samples from the Grizzly Bay station (Phillips et al., in press). TIEs have indicated that sediment-associated metals are also the cause of toxicity in samples from a southern Estuary station, though the specific metals responsible have not been identified. TIEs with amphipods have shown that the persistent toxicity observed in Grizzly Bay sediment is not likely due to organic chemicals (such as pesticides), but instead is caused by some acid-soluble contaminant, such as a metal (Anderson et al. 2000).

Monitoring information can also suggest possible solutions to toxicity problems. For example, many of these RMP stations are near urban creeks and rivers that receive seasonal stormwater runoff. By identifying the specific chemicals responsible for observed toxicity, resource managers may be able to implement studies to confirm whether urban runoff is an important source of these contaminants. Once this is confirmed, programs may be designed to reduce inputs of these chemicals to the Estuary. As a first step, a RMP special study has been proposed to monitor sediment toxicity and chemistry at the base of selected creeks and rivers during the rainy season to assess what role these sources play in contributing toxic sediments to the ecosystem.

Looking to the Future

Sediment toxicity is likely to persist for many years to come, considering the continuing toxicity observed in the RMP. Additional special studies are planned to further examine whether water and sediment toxicity tests used in the RMP are accurate predictors of impacts on the Estuary's aquatic and benthic communities. Because the amphipod (*Eohaustorius estuarius*) used in the RMP is not a resident of the Estuary, there has been some debate regarding its ecological relevance. Sensitivity of selected resident organisms to key chemicals of concern will be compared to sensitivity of this amphipod species. Similar tests are planned to evaluate the water test species. Information from these experiments will confirm whether the current species employed are adequately sensitive to represent and ensure the protection of the Estuary ecosystem.

From a Regional Board perspective, RMP toxicity monitoring has played a crucial role in tracking possible effects of contaminants in the water and sediment of San Francisco Bay and its major tributaries. Documentation of the toxicity associated with OP pesticides played an important role in the EPA's reevaluation of these pesticides. The subsequent measurement of decreasing aquatic toxicity with the coinciding decrease in OP pesticide use appears to demonstrate the success of management actions. However, since new classes of pesticides are being increasingly used to replace OP pesticides (such as pyrethroids that partition in the sediment and have higher toxicity in fish), new approaches to monitoring potential effects are needed. Continued monitoring of toxicity with associated chemical measurements, the development of TIE procedures for emerging pesticides, and the increased use of TIEs will allow us to keep current on the status of toxicity in the Estuary and its tributaries, help determine the causes of toxicity, and inform regulatory decisions.

Pyrethroid Insecticides

The implementation of U.S. EPA restrictions on the use of organophosphate (OP) insecticides has prompted pesticide manufacturers to turn to using alternatives insecticides to meet market demands. Pesticide use data (see Figure on page29) indicate that pyrethroid insecticides are one of the primary replacements of OP pesticides.

Pyrethroids are synthetic analogs of pyrethrins, a class of naturally occurring pesticides with insecticidal properties that are found in the flower heads of chrysanthemums. Pyrethrins have been harvested from chrysanthemums and used as a natural insecticide since the early 1900s. More recently, chemists modified the structure of pyrethrins to make them more chemically stable and more toxic than naturally occurring pyrethrins.

Common pyrethroids include permethrin, cypermethrin, esfenvalerate, bifenthrin, cyfluthrin, and deltamethrin, among others. They have been used as active ingredients in residential lawn and garden retail products (e.g., Ortho, Scotts, Bayer Advanced, Spectracide, and Real-Kill). Pyrethroids interfere with the function of the nervous system and very effectively block nerve impulse transmission in insects. Humans can rapidly metabolize and eliminate pyrethroids, so they appear to pose low risk to human health. However, fish and aquatic arthropods are quite sensitive to pyrethroids, raising concern for possible non-target impacts on aquatic environments due to agricultural, structural, and landscape maintenance applications.

Pyrethroids behave differently in the environment than organophosphate insecticides, with greater persistence and a stronger tendency to bind to sediment particles than organophosphates. The RMP is adjusting its toxicity monitoring to better evaluate compounds with these chemical and toxicological properties.

Ten Years of Pilot and Special Studies:
Keys to the Success of the RMP

Jay A. Davis (jay@sfei.org) – San Francisco Estuary Institute, Oakland, CA

PILOT STUDY

A monitoring study conducted on a trial basis in order to determine whether it is suitable for inclusion in RMP status and trends monitoring.

SPECIAL STUDY

A study that helps improve monitoring measurements or the interpretation of monitoring data or that serves to meet RMP objectives through activities other than monitoring.

It is widely acknowledged that the RMP has generated a world-class body of science describing contamination in San Francisco Bay, and this is an obvious sign of the success of the Program. Less obvious, but equally important to the continuing support enjoyed by the RMP, are the processes that have been established to facilitate collaboration and communication among RMP participants and to ensure efficient use of funds to answer the most pressing management questions. Stable funding has allowed the RMP to develop an efficient organizational structure and processes that enable the Program to adapt to changing management priorities and advances in scientific understanding. The RMP in 2003 looks very different from the RMP in 1993. Pilot and special studies are one of the main mechanisms that have allowed this growth and improvement.

THE MATURATION OF A MONITORING PROGRAM

In its infancy in 1993, the RMP was a $1.2 million program narrowly focused on measuring spatial and temporal trends in contaminant concentrations and toxicity in the main channel of the Estuary. In 2003 the RMP has matured into a multifaceted $3.4 million program of study that evaluates spatial and temporal trends in chemical contamination and toxicity in a more comprehensive manner, and also assesses contaminant effects, contaminant loading, and performs broad-scale synthesis of information from RMP and other programs. Pilot and special studies in the RMP have allowed the Program to adapt in response to changes in the regulatory landscape, advances in understanding of the Estuary, and a continual drive to adjust the Program to better meet its objectives.

RMP pilot and special studies have been keys to both the adaptive management of status and trends monitoring and the success of the RMP in meeting its objectives related to effects, loading, and synthesis (see RMP objectives on page 34). Adaptive management is achieved through several mechanisms in the RMP. One of these is an institutional structure with committees and workgroups (Figure 1) that meet quarterly to track progress and plan future work. This structure allows for continual adjustment of the Program. Another important mechanism by which the Program adapts is periodic Program Reviews, where independent, prominent experts in environmental monitoring evaluate the Program as a whole. Program Reviews are conducted on approximately a five-year cycle, with the most recent one occurring in 2003. Pilot and special studies are the third major mechanism by which the Program adapts. These studies constitute a mechanism for responding quickly to new information or concerns, assessing new technical approaches, investigating particular questions that have defined endpoints, and evaluating new directions for status and trends monitoring.

Pilot and special studies have been included in the RMP every year, and have lead to significant additions and refinements to status and trends monitoring. Pilot and special studies currently account for 16% of the annual budget (Figure 2). The major elements added to Status and Trends monitoring in the past 10 years that originated from pilot studies include hydrography and phytoplankton, suspended sediment dynamics, and fish contamination.

Some of the refinements resulting from special studies include ongoing development of mass budget models, an updated list of target chemicals for monitoring, an optimized bivalve monitoring program, and incorporation of surveillance monitoring and interlaboratory quality assurance exercises.

Got Ideas?

Given the importance of pilot and special studies to the success of the Program, it is essential to have an effective process for generating new study ideas and deciding which studies to fund. One of the main products of the first Program Review was a Pilot and Special Study Selection Procedure (PSSSP). The PSSSP clearly lays out the responsibilities of the parties involved in the decision-making process: the Steering Committee, Technical Review Committee (TRC), Regional Board, and SFEI. The PSSSP also lays out the steps that begin with the generation of ideas and culminate in the implementation of a well-planned study.

One of the valuable features of the procedure is that it establishes a wide funnel to channel potentially useful ideas into the process. Many ideas originate from within the committees and workgroups of the Program. However, input from scientists from outside the Program is also encouraged. These outside scientists may also end up implementing the proposed work, providing a means of broadening the scientific horizons and skills of all parties to the RMP. Ideas for new studies are solicited on the RMP web site <www.sfei.org/rmp/>.

In December of each year, the annual cycle for considering these studies begins. A list of ideas compiled through the year is evaluated by the TRC. Depending on the amount of funding available that year, a few ideas are selected for further elaboration and consideration. More detailed conceptual scopes of work are then prepared on these topics and reviewed by the TRC. In June of each year, the TRC establishes the relative priority of all of the pilot and special study concepts based on their technical merit. In July, the Steering Committee then decides which studies can be included in the next year's program. Studies that would require an increase in the overall budget of the Program have a longer planning horizon, given the minimum one year lead time needed to obtain Steering Committee approval and implement this sort of increase.

Continued on page 34

Table 1. RMP Pilot and Special Studies from 1993–2005. A large number of pilot and special studies have been conducted in the RMP. Some of the studies have become annual features of the Program as indicated in the Tables, and some have not. All of the studies, however, have yielded valuable information.

Years active
I = year incorporated into RMP

Pilot Studies

Hydrography and phytoplankton	93	I											
Suspended sediment dynamics	93	I											
Benthic macrofaunal assemblages		94	95	96	97	98							
Wetlands monitoring			95	96									
Estuary interface				96	97	98	99	00	01				
Fish contamination					97			00			I		
Episodic toxicity						98	99	00	I				
Atmospheric deposition						98	99	00	01				
Mercury deposition network									01	02	03	04	
Exposure and effects									01	02	03	04	05

Special Studies

Comparison of local effects monitoring and the RMP		94											
Optimal water quality sampling strategy		94											
Development of a chronic Ampelisca abdita bioassay		94	95										
Methods for analysis of spatial and temporal patterns (trace elements)			95										
Workshop on ecological indicators			95										
Interlaboratory comparison exercises			95										
Sediment contamination indicators				96									
Review of bivalve monitoring				96									
Sediment information synthesis						98							
Sources, pathways, and loadings literature reviews						98	99	00	01	02	I		
Mass budget models									01				
Contaminant transfer from sediment to biota									01				
Surveillance monitoring									01	02			
CTR monitoring										02	03		
Loads from rivers										02	03	04	
10 year synthesis											03	04	

RMP Objectives

- Describe patterns and trends in contaminant concentration and distribution
- Describe general sources and loading of contamination to the Estuary
- Measure contaminant effects on selected parts of the Estuary ecosystem
- Compare monitoring information to relevant water quality objectives and other guidelines
- Synthesize and distribute information from a range of sources to present a more complete picture of the sources, distribution, fates, and effects of contaminants in the Estuary ecosystem

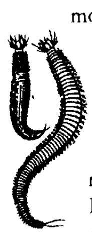
Pilot and Special Study Highlights, 1993-2003

A large number of pilot and special studies have been conducted in the RMP since 1993 (Table 1, previous page). Some of the studies have become annual features of the Program, and some have not. All of the studies, however, have yielded valuable information. Highlights of the major studies are described below. Technical reports are available at <www.sfei.org>.

Hydrography and Phytoplankton and Suspended Sediment Dynamics.

See articles by Cloern et al. and Schoellhamer et al. in this issue.

Benthic Pilot



Benthic organisms are known to be sensitive to sediment contamination, and benthic community monitoring is used in all large state and federal monitoring programs. Looking towards including a biological effects component in the RMP, the Benthic Pilot Study was conducted from 1994 – 1998. This study identified the major benthic communities in the Estuary, and the data were used to develop an assessment method to evaluate possible benthic impacts from sediment contamination. Benthic indicators of sediment contamination are being further refined under the Exposure and Effects Pilot Study (see below).

Sediment Toxicity Testing

The RMP began using the amphipod *Eohaustorius estuarius* for sediment toxicity monitoring in 1993. However, it is not a resident species. Another amphipod, *Ampelisca abdita*, is often dominant in benthic samples in the Estuary. This special study was conducted to develop a resident species for use in RMP sampling. The study compared the two species sensitivities to contaminants and evaluated the efficacy of collecting and interpreting toxicity to *A. abdita*. That species is seasonal in abundance, making a reliable supply of organisms difficult. Further, resident specimens were comparatively tolerant of contaminated sediments. The use of *A. abdita* is currently being further investigated in the Exposure and Effects Pilot Study (see below).

RMP Committee Organization Chart

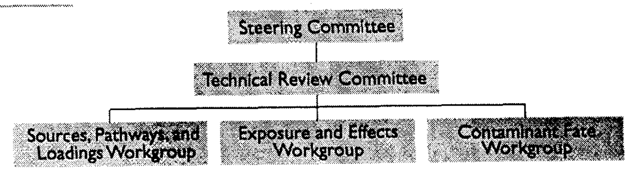


Figure 1. RMP committee organization. The three workgroups address the three main technical subject areas covered by the RMP. Workgroups consist of local scientists and regulators and invited scientists recognized as leaders in their field. The Workgroups directly guide planning and implementation of pilot and special studies. Activities of the Workgroups and the technical content of the RMP as a whole are directed by the Technical Review Committee. The Steering Committee determines the overall budget, allocation of program funds, tracks progress, and provides direction to the Program from a manager's perspective.

Wetlands Monitoring

The Wetlands Monitoring Pilot Study was conducted in 1995 and 1996. This study pioneered the use of the natural anatomy of Bay tidal marshes as a template for sampling chemical contamination. Taking this anatomy into account is essential to gathering data that can be compared among marshes. The number of samples collected was small, but the study provided a preliminary indication of the degree and variability of contamination of two Bay marshes. The results suggested that marsh sediments were more contaminated than sediments from nearby stations in the open Bay. Wetlands monitoring was not incorporated in the status and trends program because the Steering Committee decided to focus on development of the subtidal RMP. However, the Wetland Pilot did provide a foundation for the ongoing development of a Wetland Regional Monitoring program that is currently conducting much more intensive pilot monitoring studies of Bay wetlands using State and U.S. EPA funding.

Estuary Interface

The Estuary Interface Pilot Study was performed from 1996 – 2001, with funding provided by RMP and the City of San Jose. The goal of the study was to describe how surface runoff from two local watersheds might influence water quality in the Bay; this influence was found to be considerable. Concentrations of many priority contaminants in water and sediment were elevated at the two EIP stations relative to several other Bay segments, suggesting that the Guadalupe River and Coyote Creek watersheds were sources of these contaminants to the Lower South Bay. A particularly strong signal of mercury contamination from the Guadalupe River watershed was detected, tracing to historic mining activities in the New Almaden district. This information and other studies have identified inputs from the Guadalupe River watershed as a dominant influence on mercury in the South Bay, and led regulators to focus on this region in their efforts to reduce mercury contamination in the Bay through the TMDL process. The EIP Study also played an integral part in the development of a small tributaries loading study by the Sources, Pathways, and Loadings Workgroup. SFEI began a loading study on the Guadalupe River in late 2002 with funding from the Clean Estuary Partnership. The Estuary Interface Pilot Study was discontinued in 2002 when the status and trends program switched to a spatially randomized sampling design.

Fish Contamination

The Fish Contamination Pilot Study was performed in 1997, following up on a 1994 study conducted under the Bay Protection and Toxic Cleanup Program. Fish contamination monitoring was incorporated into the status and trends program in 2000. RMP fish contamination monitoring is the primary source of information used in evaluating the need for a fish consumption advisory for the Bay. The existence of this advisory is a principal reason that the Regional Board is developing total maximum daily loads (TMDLs) in an effort to reduce concentrations of mercury and PCBs in the Bay. Contaminant concentrations in sport fish provide an important target for tracking the necessity and effectiveness of TMDLs.

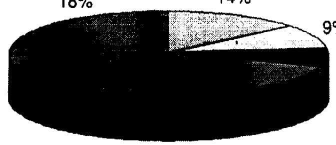
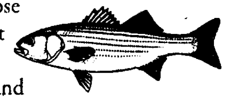


Figure 2. The RMP budget in 2003. Pilot and Special Studies accounted for 16% of the total budget.

Seafood Consumption

The RMP (as a special study) and the California Department of Health Services sponsored a study of fish consumption by Bay anglers in 1998 and 1999. About one in ten anglers was found to eat more than the amount recommended in the Bay consumption advisory. Asian anglers stood out as a group of concern due to their large numbers, consumption rates, and methods of preparation and consumption. Only about one quarter of the anglers interviewed had specific knowledge of the consumption advisory. Fostering increased awareness among those consuming Bay fish is the most rapid means of reducing risks posed by fish contamination, and represents an important complement to efforts to reduce contaminant concentrations. Education and outreach efforts based on the San Francisco Bay Seafood Consumption Study have been conducted.



Atmospheric Deposition

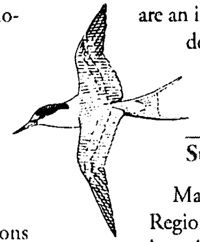
Atmospheric deposition was identified by the Sources, Pathways, and Loadings Workgroup as a potentially significant pathway for contaminant loading to the Bay. The Atmospheric Deposition Pilot Study, combining funding from RMP and the City of San Jose, was conducted from 1998 – 2000. Atmospheric deposition was found to contribute significant loads of contaminants, particularly mercury and PAHs. Atmospheric deposition of mercury directly to the surface of the Bay and entering the Bay through atmospheric deposition to watershed surfaces followed by stormwater transport amounted to a significant portion of the Bay mercury mass budget. Much of the atmospheric mercury load is attributable to global atmospheric mercury contamination. The study similarly suggested that atmospheric deposition of PAHs is significant in the overall mass budget for PAHs in the Bay, and should be a subject of management concern. The Atmospheric Deposition Pilot Study ended in 2000 having answered the fundamental questions posed at the beginning of the Study.

Episodic Toxicity

From 1996–2000 the RMP, with funds also contributed by East Bay Dischargers Authority, conducted the Episodic Toxicity Pilot Study. In the first years of the RMP, aquatic toxicity testing was performed on the same schedule and at the same locations as the water sampling for chemical analysis. Significant toxicity observed after storms in 1996 and 1997 led the Program to conduct more targeted sampling at the times (after storms) and places (tributary mouths) where toxicity was most likely to be observed. Study results indicated that toxicity was present in parts of the Bay primarily after runoff events. Some of the toxicity appeared to be associated with organophosphate pesticides, but other unidentified chemicals also appeared to be involved. Toxicity declined over the course of the Study, possibly due to decreasing use of organophosphate pesticides. Episodic toxicity evaluation became part of status and trends monitoring in 2001. For further discussion of aquatic toxicity testing in the RMP from 1993–2002, see page 27.

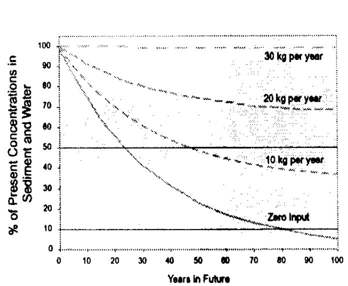
Exposure and Effects

In response to the new objective to measure contaminant effects, the RMP is conducting a pilot study on exposure and effects of contaminants. This five year (2002 – 2006) study is multifaceted, including a variety of different indicators: diving duck muscle (a human exposure indicator), cormorant and Forster's tern eggs (chemical trend indicators), hatchability of Forster's terns, least terns, and clapper rails (effects indicators), blood chemistry and biomarkers in harbor seals (exposure and effects indicators), effects studies in fish, aquatic and sediment toxicity testing of resident species (effects), and benthic community evaluations (effects). These indicators will be valuable in evaluating impairment of beneficial uses (through toxic impacts on wildlife and human health) and tracking effectiveness of management actions to reduce contamination in the Bay.



Fate Models

In 2001 a Mass Budget Model special study was performed. Mass budget models are valuable in many ways: summarizing the existing state of knowledge, synthesizing information from the RMP and other programs on contaminants in San Francisco Bay, predicting the response of contaminant concentrations in the Bay to management actions and natural processes, identifying and prioritizing data gaps, and communicating RMP results. Mass budget models have been developed for PCBs, PAHs, and organochlorine pesticides. This study also included development of a food web model for PCBs that links concentrations in sediment to concentrations in sport fish indicator species. The PCB mass budget and food web models are an integral part of the PCB TMDL. Model development and other data integration tasks became incorporated into the status and trends program in 2002.

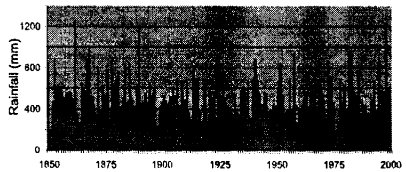


Surveillance Monitoring

Many of the contaminants regulated by the Regional Board and monitored in the RMP have been banned or strictly regulated for decades. In 2000 a surveillance component was added to the RMP to allow for more proactive management of Bay contamination. To initiate this surveillance monitoring, a special study was conducted to determine the presence of emerging contaminants in archived RMP samples. Many organic contaminants were found and are considered to be of potential concern, including flame retardants (polybrominated diphenyl ethers, or PBDEs), detergent ingredients (nonylphenol and alkylbenzenes), and constituents of plastics (phthalates). Based partially on these findings, PBDEs were added to the 303(d) watch list in 2001. In 2002, the emerging chemicals of concern were included in RMP status and trends monitoring to investigate their occurrence in recent samples. Those chemicals that are found at levels of concern will continue to be measured in annual RMP sampling. As emerging contaminants are identified in the RMP, the Regional Board will enlist the assistance of stakeholders to find the best ways of reducing or eliminating those that are a threat to human and wildlife health.

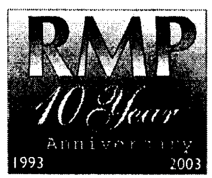
Sources, Pathways, and Loadings/Urban Runoff Literature Review

The Sources, Pathways, and Loadings Workgroup was formed in 1998 to produce recommendations for incorporating collection, interpretation, and synthesis of data on general sources and loading of trace contaminants to the Estuary into the RMP. Contaminant loading is a topic well suited to special studies, where focused, short-term projects can answer specific questions about the relative importance of inputs from different pathways. In 1999, the Sources, Pathways, and Loadings Workgroup conducted a literature review on loading of priority contaminants to the Bay and recommended a series of steps to assess the potential significance of contaminant loads to the Bay from urban runoff. One of the recommendations of the Workgroup was to develop and document our conceptual understanding of transport by stormwater through urban watersheds as a prelude to making actual measurements of loads. A second major literature review assembled information on climate and hydrology, suspended sediment, PCBs, organochlorine pesticides, and mercury and formulated recommendations for sampling small tributaries based on this information. The final report from this effort will be available in summer 2003. The review provided the conceptual foundation for the Clean Estuary Partnership's Guadalupe River Loading Study, which began measurement of loads from this high priority watershed in November 2002.



River Loads

The Sources, Pathways, and Loadings Workgroup determined that loads to the Bay from the Sacramento and San Joaquin rivers are potentially significant components of the mass budgets for many contaminants. In 2002 SFEI began a three- year special study to estimate loads of priority contaminants at Mallard Island, a sampling location just downstream of the confluence of the two rivers. The loads will be estimated by establishing the statistical relationship between suspended sediment concentrations, which can be measured continuously, and contaminant concentrations, which must be measured less frequently due to the expense of chemical analysis. This approach will provide load estimates that characterize the large loads that occur over short timespans due to winter storms. Understanding the role of river inputs in contaminant mass budgets for the Bay will provide essential context for evaluating the potential effectiveness of actions taken to reduce Bay contamination, especially for mercury and DDT.

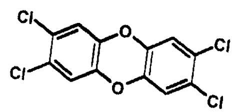


10 Year Synthesis

A highlight of the RMP in 2003 and 2004 is a special study to perform a thorough review of the first ten years of the RMP. In 2001 the RMP finished status and trends sampling employing the original fixed station design. The end of this initial chapter of the RMP is an appropriate time to perform a rigorous evaluation of trends indicated by the original status and trends program design. Ten years of monitoring also represents a substantial body of work for the other aspects of the RMP, and a synthesis of findings from these elements is also worthwhile at this time. In addition, the last synthetic overview of contamination in the Estuary was completed in 1991 (the San Francisco Estuary Project's Status and Trends Report on Pollutants: Davis et al. 1991), and Bay contamination, and understanding and regulation of Bay contamination, have changed considerably since that time. This study will produce a sequel to the 1991 Status and Trends Report.

CTR Monitoring

A short term, but significant, addition to the Program in 2003 is a special study to measure concentrations of priority pollutants in the Bay that are included in the California Toxics Rule (CTR), but have not previously been examined in ambient Bay waters. Some of the chemicals include dioxins, cyanide, phthalates, volatile and semi-volatile organics, and several trace elements. This study is being conducted in response to NPDES permit provisions for wastewater dischargers. This two-year special study began in 2002 and will end in 2003. Sampling to provide data needed specifically for NPDES permit development may continue to be part of the RMP after this study ends.



REFERENCES

Lessons from Monitoring Water Quality in San Francisco Bay

Alpine, A.E. and J.E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnology and Oceanography 37: 946-955.

Beck, N.G., K.W. Bruland and E.L. Rue. 2002. Short-term biogeochemical influence of a diatom bloom on the nutrient and trace metal concentrations in South San Francisco Bay microcosm experiments. Estuaries 25: 1063-1076.

Brown, C.L. and S.N. Luoma. 1999. Metal trends and effects in *Potamocorbula amurensis* in North San Francisco Bay. <http://toxics.usgs.gov/pubs/wri99-4018/Volume2/sectionA/2202_Brown/index.html>.

Brown, C.L., F. Parchaso, J.K. Thompson and S.N. Luoma. 2003. Assessing toxicant effects in a complex estuary: a case study of effects of silver on reproduction in the bivalve *Potamocorbula amurensis*, in San Francisco Bay. Human and Ecological Risk Assessment 9: 95-119.

Chavez, R.P., J. Ryan, S. E. Lluch-Cota, and M. Yiquen C. 2003. From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science 299: 217-221.

Cloern, J.E. and R.S. Oremland. 1983. Chemistry and microbiology of a sewage spill in South San Francisco Bay. Estuaries 6: 399-406.

Cloern, J.E. 1996. Phytoplankton bloom dynamics in coastal ecosystems: A review with some general lessons from sustained investigation of San Francisco Bay, California. Reviews of Geophysics 34: 127-168.

Jassby, A.D., J.E. Cloern and T.M. Powell. 1993. Organic carbon sources and sinks in San Francisco Bay: variability induced by river flow. Marine Ecology Progress Series 95: 39-54.

Jassby, A.D., B.E. Cole and J.E. Cloern 1997. The design of sampling transects for characterizing water quality in estuaries. Estuarine, Coastal and Shelf Science 45: 285-302.

Luoma, S.N., A. Van Geen, B.G. Lee and J.E. Cloern. 1998. Metal uptake by phytoplankton during a bloom in south San Francisco Bay: Implications for metal cycling in estuaries. Limnology and Oceanography 43: 1007-1016.

Orsi, J.J. and W.L. Mecum. 1996. Food limitation as the probable cause of a long-term decline in the abundance of *Neomysis mercedis* the Opossum Shrimp on the Sacramento-San Joaquin estuary. Pp. 375-402, in J.T. Hollibaugh (ed.), San Francisco Bay: The Ecosystem. Pacific Division, AAAS, San Francisco.

Sobczak, W.S., J.E. Cloern, A.D. Jassby and A.B. Mhller. 2002. Bioavailability of organic matter in a highly disturbed estuary: The role of detrital and algal resources. Proceedings of the National Academy of Science 99: 8101-8105.

Bay Sediment Dynamics Drive Bay Contaminant Dynamics

Barad, M.F., Schladow, S.G., Warner, J.C., and Schoellhamer, D.H., 2001, CISNet San Pablo Bay Network of Environmental Stress Indicators: The CISNet Hydrodynamic Database: Proceedings of the 5th biennial State of the Estuary Conference, San Francisco, Calif., October 9-11, 2001, p. 112. URL: http:http://ca.water.usgs.gov/abstract/sfbay/abstractsec2001.html

Buchanan, P.A., and Ganju, N.K., 2002, Summary of suspended sediment concentration data, San Francisco Bay, California, water year 2000: U.S. Geological Survey Open File Report 02-146. URL http://water.usgs.gov/pubs/of/ofr02146/

Buchanan, P.A., and Ruhl, C.A., 2001, Summary of suspended sediment concentration data, San Francisco Bay, California, water year 1999: U.S. Geological Survey Open File Report 01-100, 56 p. URL http://water.usgs.gov/pubs/of/ofr01-100/

Davis, J.A., 2003, The Long Term Fate of PCBs in San Francisco Bay: Regional Monitoring Program Technical Report 66, San Francisco Estuary Institute, Oakland, Calif.

Davis, J.A., Abu Saba, K., and Gunther, A.J. 1999. Technical report of the Sources Pathways and Loadings Workgroup. San Francisco Estuary Regional Monitoring Program for Trace Substances. San Francisco Estuary Institute, September 1999. 55pp.

Davis, J.A., McKee, L.J., Leatherbarrow, J.E., and Daum, T.H., 2000. Contaminant loads from stormwater to coastal waters in the San Francisco Bay region: Comparison to other pathways and recommended approach for future evaluation. San Francisco Estuary Institute, September 2000. 77pp.

Gilbert, G.K., 1917, Hydraulic mining debris in the Sierra Nevada: U.S. Geological Survey Professional Paper 105.

Jaffe, B.E., Smith, R.E., and Torresan, L.Z., 1999, Sedimentation and bathymetric change in San Pablo Bay, 1856-1983: U.S. Geological Survey Open-File Report 98-759. URL http://sfbay.wr.usgs.gov/access/sanpablobay/bathy/home.html

Krone, R.B., 1979, Sedimentation in the San Francisco Bay system: In T.J. Conomos (ed.), San Francisco Bay, The Urbanized Estuary, Pacific Division of the American Association for the Advancement of Science, San Francisco, California, pp. 347≠385.

McKee, L., Ganju, N.K., and Schoellhamer, D.H., Davis, J.,Yee, D., Leatherbarrow, J., and Hoenicke, R., 2002, Estimates of suspended sediment flux entering San Francisco Bay from the Sacramento and San Joaquin Delta: Regional Monitoring Program Technical Report.

Marvin-DiPasquale, M.C., Agee, J.L., Bouse, R.M., and Jaffe, B.E., 2003, Microbial cycling of mercury in contaminated pelagic and wetland sediments of San Pablo Bay, California: Environmental Geology, v. 43, p. 260-267.

Ogden Beeman & Associates, Inc., 1992, Sediment budget study for San Francisco Bay: Report prepared for the San Francisco District, U.S. Army Corps of Engineers.

Porterfield, G., 1980, Sediment transport of streams tributary to San Francisco, San Pablo, and Suisun Bays, California, 1909–1966: U.S. Geological Survey Water-Resources Investigations Report 80-64, 91 p.

Regional Monitoring Program, 2002, Pulse of the Estuary, 2000 Update: San Francisco Estuary Institute, Oakland, California.

Schoellhamer, D.H., 2002, Variability of suspended sediment concentration at tidal to annual time scales in San Francisco Bay, USA: Continental Shelf Research, v. 22, p. 1857-1866. http://ca.water.usgs.gov/abstract/sfbay/savar_csr_pecs2000.pdf

Uncles, R.J., and Peterson, D.H., 1995, A computer model of long-term salinity in San Francisco Bay: sensitivity to mixing and inflows: Environmental International, v. 21, no. 5, p. 647-656.

Wright, S.A. and Schoellhamer, D.H., 2003, Trends in the sediment yield of the Sacramento River, 1957-2001: Proceedings of the 2003 CALFED

Ten Years of Testing for the Effects of Estuary Contamination

Anderson BS, Phillips, BM, Hunt, and Sericano, J. 2000. Investigations of chemicals associated with amphipod mortality at two regional monitoring program stations. Technical report to the San Francisco Estuary Institute – Regional Monitoring Program.

Basin Plan 1995. Regional Water Quality Control Plan, San Francisco Basin (Region 2). June 21, 1995. California Regional Water Quality Control Board, Oakland, CA.

Davis, J.A., A.J. Gunther, J.M. O'Connor, B.J. Richardson, R.B. Spies, E. Wyatt, and E. Larson. 1991. Status and Trends Report on Pollutants in the San Francisco Estuary. San Francisco Estuary Project, Oakland, CA.

Foe, C. 1995. Insecticide concentrations and invertebrate bioassay mortality in agricultural return water from the San Joaquin Basin. Staff Report. Central Valley Regional Water Quality Control Board, Sacramento, CA.

Foe, C., L. Deanovic, and D. Hinton. 1998. Toxicity Identification Evaluations of orchard dormant spray storm runoff. California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA.

Katznelson, R. and Mumley, T. "Diazinon in Surface Waters in the San Francisco Bay Area: Occurrence and Potential Impact," Report to California State Water Resources Control Board and Alameda Countywide Clean Water Program, Oakland, CA, June (1997).

Lucas, L.V., Koseff, J.R., Cloern, J.E., Monismith, S.G., and Thompson, J.K., 1999, Processes governing phytoplankton blooms in estuaries, Part I, The local production-loss balance: Marine Ecology Progress Series, v. 187, p. 1-15.

Obrebski S, Orsi JJ, Kimmerer W (1992) Long-term trends in zooplankton distributions and abundance in the Sacramento-San Joaquin Estuary. Technical Report 32, Interagency Ecological Program (IEP), CA Department of Water Resources, Sacramento, CA.

Ogle, S., A. Gunther, and R. Hoenicke. 1998. Episodic toxicity in the San Francisco Bay system. Interagency Ecological Program Newsletter 11(2):14-17.

Parchaso, F., and Thompson, J.K., 2002, Influence of hydrologic processes on reproduction of the introduced bivalve Potamocorbula Amurensis in Northern San Francisco Bay, California: Pacific Science, v. 56, no. 3, p. 329-345.

Phillips, B., B. Anderson, and J. Hunt. 2000. Investigations of sediment elutriate toxicity at three estuarine stations in San Francisco Bay. Draft Report. San Francisco Estuary Institute, Richmond, CA.

Phillips, BM, Anderson, BS, Hunt, JW, Thompson, B, Lowe, S, Hoenicke, R, Tjeerdema, RS. In press. A weight-of-evidence approach to investigating causes of sediment toxicity in San Francisco Bay, California. Arch. Environ Contam. Toxicol.

RMP News, Vol 6:2, <http://www.sfei.org/rmp/rmp_news/rmpnews_vol6_issue2.pdf>

Science Conference, Sacramento, California, January 14-16, 2003, p. 177.

S.R. Hanson and Associates. 1995. Final Report: Identification and Control of Toxicity in Stormwater Discharges to Urban Creeks. Prepared for Alameda County Urban Runoff Clean Water Program.

Thompson, B., B. Anderson, J. Hunt, K. Taberski, and B. Phillips. 1999. Relationships between sediment contamination and toxicity in San Francisco Bay. Marine Env. Research 48:285-309.

RMP Technical Review Committee

POTWs, Diane Griffin, EBMUD

South Bay Dischargers, Tom Hall, EOA Inc.

Refiners, Bridgette DeShields, Harding Lawson Associates

Industry, Maury Kallerud, USS-POSCO

Stormwater Agencies, Chris Sommers, EOA, Inc.

Dredgers, Andy Jahn, Port of Oakland

Regional Board 2, Karen Taberski

Regional Board 5, Chris Foe

U.S. EPA, Kathleen Dadey

City of San Jose, **David Tucker**

City/County of San Francisco, Michael Kellogg

RMP Technical Review Committee Chair in bold print

RMP Steering Committee

Small POTWs, Ken Kaufman, South Bayside System Authority

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

Large POTWs, Chuck Weir, East Bay Dischargers Authority

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

Industry, Maury Kallerud, USS-POSCO

Cooling Water, Steve Bauman, Mirant of California

Stormwater Agencies, Larry Bahr, Fairfield-Suisun Sewer District

Dredgers, Ellen Johnck, Bay Planning Coalition

SFBRWQCB, Dyan Whyte

RMP Steering Committee Chair in bold print

RMP Program Participants in 2001

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

Dow Chemical Company

General Chemical Corporation

Phillips 66 at Rodeo

Rhodia, Inc.

Shell-Martinez Refining Company

Tesoro, Avon Refinery

USS-POSCO Industries

Valero Refining Company

Cooling Water

Mirant of California

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

Vallejo Sanitation and Flood Control District

Dredgers

Benicia Industries

Chevron Products Company

Caltrans – San Mateo Bridge

Larkspur Ferry

Loch Lomand MarinaMM

Marin Rowing Association

Marin Yacht Club

Port of Oakland

Port of San Francisco

San Mateo County – Oyster Point

Schnitzer Steel

Sierra Point Marina

Shore Terminals

Timmers Landing

TOSCO Corporation

US Army Corps of Engineers

Valero Refining

The Pulse of the Estuary

Editors:
Jay Davis, Patricia Chambers, Michael Connor, Michael May

Contributing authors:
Jay Davis, Sarah Lowe, others as indicated

Information compilation:
Nicole David, Cristina Grosso, Jennifer Hunt, Jon Leatherbarrow, Sarah Lowe, Lester McKee, Daniel Oros, John Ross, Donald Yee

Report design & layout:
Patricia Chambers

Front cover design:
PercyDesign
www.percydesign.com

Printing:
Alonzo Printing
Hayward, CA

Copies of this report can be obtained by calling SFEI at (510) 746-7334

This report is also available on the web at <www.sfei.org>.

Acknowledgements

The efforts of those who provided comments on a draft of this edition of the *Pulse* are gratefully acknowledged:

Diane Griffin, Tom Hall, Jennifer Hunt, Daniel Oros, Lisa Owens-Viani, John Ross, Karen Taberski, Bruce Thompson, Dave Tucker, and Sheila Tucker.

A · Primer · on · Bay · Contamination

Q: How contaminated is the Estuary?

A: Water and sediment of the Estuary meet cleanliness guidelines for most contaminants. In 2001, 90% of chemical concentrations measured in water were below their guideline, and 70% of chemical concentrations measured in sediment were below their guideline. However, a few problem contaminants are widespread in the Estuary, making it rare to find water or sediment in the Estuary that is completely clean. Of the recent (1997–2001) water and sediment samples collected by the Regional Monitoring Program (RMP), about 61% and 90% contained at least one contaminant at a level that failed to meet established guidelines, respectively. A fish consumption advisory remains in effect due to concentrations of mercury, PCBs, dioxins, and organochlorine pesticides of potential human health concern in Bay sport fish. A duck consumption advisory is also in effect due to selenium concentrations of potential human health concern. Toxicity testing over the past 10 years has found that about 13% of water samples and 63% of sediment samples tested were toxic to at least one species of test organism. The 303(d) list and the 303(d) watch list are the official lists of contaminants of concern in the Estuary (see facing page).

Q: Are contaminants harming populations of organisms in the Estuary?

A: This critical question remains largely unanswered. There are indications that the current level of contamination is harming the health of the ecosystem, such as the frequent occurrence of contaminants above water and sediment guidelines, and the toxicity of water and sediment samples to lab organisms. Mercury concentrations appear to be high enough to cause embryo mortality in clapper rails, an endangered species found in Bay tidal marshes. PCB concentrations may be high enough to also cause low rates of embryo mortality in Bay birds and to affect immune response in harbor seals. Assessments of benthic communities in the marine and estuarine regions of the Bay indicate that some areas may be impacted by contaminants. The RMP began a focused investigation of contaminant effects in 2002; results will begin to be available by the next *Pulse*.

Q: Is the contamination getting better or worse?

A: Over the long term, the Estuary has shown significant improvements in basic water quality conditions, such as the oxygen content of Estuary water, due to investments in wastewater treatment (see article on page 15). Contamination due to toxic chemicals has also generally declined since the 1950s and 1960s. More recently, however, the answer to this question varies from contaminant to contaminant. Mercury concentrations in striped bass, a key mercury indicator species for the Estuary, have shown little change in 30 years. PCB concentrations appear to be gradually declining based on trends observed in mussels, fish, and birds. Concentrations of DDT, chlordane, and other legacy pesticides have declined more rapidly and may soon generally be below levels of concern. On the other hand, concentrations of chemicals in current use, such as pyrethroid insecticides and polybrominated diphenyl ethers (PBDEs) are suspected to be on the increase. Aquatic toxicity has declined in the past few years, possibly associated with reduced usage of organophosphate pesticides. Sediment toxicity, on the other hand, has consistently been observed in a large proportion of samples tested over the past ten years.

Q: Do we know how to clean up the Estuary?

A: There are three general approaches to Estuary clean-up.

1. Reducing the entry of additional contaminants is essential. The Estuary acts as a long term trap for persistent contaminants; once contaminants enter the Estuary it takes a very long time for them to exit. Preventing contaminants from entering the Estuary is therefore imperative. Preventing a contaminant from entering the Estuary requires knowledge of its source or an interceptable part of its path to the Estuary. We are developing detailed descriptions of the sources, pathways, and repositories of contamination for several contaminants of concern. Much of this effort is in response to the Clean Water Act's requirement to develop contaminant clean-up plans known as Total Maximum Daily Loads (TMDLs, see page 11). While known contaminant problems are being addressed by TMDLs, surveillance monitoring is conducted in the RMP in an effort to provide an early warning for contaminants of emerging concern and allow for management actions to nip potential problems in the bud.

2. Removing some masses of contaminants from the Estuary is possible. Contaminated sediment can be dredged from the Estuary, placed on land and sealed with a layer of asphalt or similar material. Such dredging has been attempted in a few cases with mixed results.

3. Allowing contaminants to degrade and disperse naturally is necessary. Time will always be a large part of the remedy, naturally reducing the large quantity of contaminants now in the sediments through degradation, and transport to the ocean and atmosphere. Burial in deep sediment is normally a removal process in estuaries, but due to a reduced supply of sediment to the Estuary (see page 21), burial is not occurring. For persistent contaminants found in large amounts in the sediments of the Estuary, such as mercury and PCBs, the time required to see change will be decades.

附件三

RAPID TRASH ASSESSMENT
Surface Water Ambient Monitoring Program

RAPID TRASH ASSESSMENT
Surface Water Ambient Monitoring Program
California Regional Water Quality Control Board, San Francisco Bay Region

Monitoring Design. The rapid trash assessment can be used for a number of purposes, such as ambient monitoring, evaluation of management actions, determination of trash accumulation rates, or comparing sites with and without public access. Ambient monitoring efforts should provide information at sites distributed throughout a waterbody, and several times a year to characterize spatial and temporal variability. Additionally, the ambient sampling design should document the effects of episodes that affect trash levels such as storms or community cleanup events. Pre- and post-project assessments can assist in evaluating the effectiveness of management practices ranging from public outreach to structural controls, or to document the effects of public access on trash levels in waterbodies (e.g., upstream/downstream). Such evaluations should consider trash levels over time and under different seasonal conditions. Revisiting sites where trash was collected during previous assessments enables the determination of accumulation rates. This methodology was developed for sections of wadeable streams, but can be adapted to shorelines of lakes, beaches, or estuaries. Ultimately, the monitoring design will strongly affect the usefulness of any rapid trash assessment information.

Site Definition. Upon arrival at a designated monitoring site, a team of two people or more defines or verifies a 100-foot section of the stream or shoreline to analyze, associated with a sampling location (station). When a site is first established, it is recommended that the 100-foot distance be accurately measured with a tape (or rope of predetermined length). The length should be measured not as a straight line, but as 100 feet of the actual stream or shore length, including sinuous curves. The starting and ending points of the survey should be easily identified landmarks, such as an oak tree or boulder, and noted on the worksheet ("Upper/Lower Boundaries of Reach"), or documented using global positioning system (GPS), so that future assessments are made at the same location. The team should confer and document the upper boundary of the banks or shore to be surveyed, based on evaluation of whether trash can be carried to the water body by wind or water (e.g., an upper terrace in the stream bank). The team should also document the location of the bankfull height based on site-specific physical indicators. Defining these characteristics of the site will facilitate comparing assessments conducted at the same site at different times of the year.

Survey. The survey should not take more than 30 minutes, and with practice, 20 minutes or less. The team begins the survey at one end of the selected reach. One team member (the "bank person") begins walking along the bank (where possible), looking for any trash on the stream (or shore) bank, or above the high water line, and tallies any trash items found on the trash assessment sheet. The other person (the "bed person") walks along the stream bed (or in the water at shorelines) and shouts out any trash items found in the water body for the person on land to tally on the trash assessment sheet. When the team has finished the survey of the stream bed and one bank, the "bank person" crosses to the other bank. Continuing the assessment, the team works their way back along the reach, with the bank person surveying the opposite bank and the "bed person" re-examining the stream bed or collecting trash, making sure not to count items twice. Alternatively, one team member can carry a garbage bag and collect trash as it is located, making sure to avoid injuries by using gloves. Avoid touching trash with unprotected hands!

The person tallying the trash notes on the sheet whether the trash was found in the stream and below bankfull, or above bankfull (i.e., tally lines for below bankfull (|) and tally dots or circles (•) for above). A pole or similar tool should be used to help look under bushes, logs, and other plant growth to see if trash has accumulated underneath. The ground or substrate should be carefully inspected to ensure that small items such as cigarette butts and pieces of broken glass or Styrofoam are being included. Because this is a rapid assessment, the tally is not exact, but it is important not to miss items that can affect human health, because such items can strongly affect the total score.

When the surveyors are finished with the tallying, they should fill out the worksheet before leaving the site, while everything is still fresh in the memory. They should discuss each number so that they agree on every score. They should discuss and document the factors affecting trash levels at the site, such as a park, school, or nearby residences or businesses. The system provides a range of 5 numbers within a given condition category, allowing for the range of conditions expected in the field. For instance, trash located in the water leads to lower scores than trash above the stream bank. Under each of the six trash assessment parameters, the narrative language is provided to assist with choosing a score within the range. Not all specific trash conditions mentioned in the narratives need to be present to fit in a specific condition category (e.g., "site frequently used by people"), nor do the narratives describe all possible conditions. The "Poor" condition category has a range of 6 numbers (0-6), unlike the other 3 condition categories. Scores of "0" should be reserved for the most extreme conditions. Once the scores are assigned for the 6 categories, they should be totaled up and any specific notes on the site should be written in the designated space at the end of the sheet. A given site should be assessed several times in a given year, during different seasons, to characterize the variability and persistence of trash occurrence for water quality assessment purposes.

Trash Assessment Parameters. The rapid trash assessment includes a range of parameters that capture the breadth of issues associated with trash and water quality. The first two parameters focus on qualitative and quantitative levels of trash, the second two parameters estimate actual threat to water quality, and the last two parameters represent how trash enters the water body at a site, through direct dumping or accumulation.

1. **Level of Trash.** This assessment parameter is 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 that is noticeable about the waterbody. No trash should be obviously visible at sites that score in the "optimal" range.

2. **Actual Number of Trash Items Found.** Based on the tally of trash along the 100-foot stream reach, total the number of items both above and below the high water mark, and choose a score within the appropriate condition category based on the range of items provided. Choose a score among the 5 numbers that is adjusted based on where the tally lies in the provided range. Where more than 50 items have been tallied, assign the following scores: 5: 51-75 items; 4: 76-100 items; 3: 101-150 items; 2: 151-200 items; 1: 201-250 items; 0: over 250 items. Since these tallies do not significantly affect the overall score, it is ok to estimate the tally at sites with more than 100 items, making sure to identify trash items that can affect human health like diapers, pet or human waste, or medical waste.

   Sometimes items are broken into many pieces. Fragments with higher threat to aquatic life such as plastics should be enumerated, while ripped paper and broken glass, with lower threat and/or mobility, should be counted based on the parent item(s). The judgment whether to count all fragments or just one item depends on the potential exposure to downstream fish and wildlife, and waders and swimmers at a given site. Concrete is trash when it is dumped, but not when it is placed. Consider tallying only those items that would be removed in a restoration or cleanup effort.

3. **Threat to Aquatic Life.** As indicated in the technical notes, below, certain characteristics of trash makes it more harmful to aquatic life. If the trash items are persistent in the environment, buoyant (floatable), and relatively small, they can be transported long distances and be mistaken by wildlife as food items. Larger items can cause entanglement. Some discarded debris may contain toxic substances. All of these factors are considered in the narrative descriptions in this assessment parameter.

4. **Threat to Human Health.** Items that are more dangerous to people that wade or swim in the water weight this category of trash assessment. The worst conditions are associated with the potential for presence of dangerous bacteria or viruses, such as medical waste, diapers, and human or pet waste. Also included in this category are sources of pollutants that could accumulate in fish in the downstream environment, such as mercury.

5. **Illegal Dumping and Littering.** This assessment category relates to direct placement of trash items at the site, and the "poor" conditions are ascribed to sites that are obviously chronic dumping locations or "trash hotspots."

6. **Accumulation of Trash.** This assessment category relates to accumulation of trash items from upstream locations. Accumulated trash is distinguished from dumped trash by indications of age and transport. For instance, faded colors, silt marks, trash wrapped around roots, and signs of decay indicate accumulated trash. Trash accumulation is an indicator that the local drainage system facilitates conveyance of trash to water bodies, in violation of clean water laws and policies.

Technical Notes on Trash and Water Quality

Trash is a water pollutant that has a large range of characteristics of concern. Not all litter and debris delivered to streams are of equal concern to water quality. Besides the obvious negative aesthetic effects, most of the harm of trash in surface waters is imparted to aquatic life in the form of ingestion or entanglement. Some elements of trash exhibit significant threats to human health, such as discarded medical waste, human or pet waste, or even broken glass. Also, some household and industrial wastes may contain toxic substances of concern to human health and wildlife, such as batteries, pesticide containers, and fluorescent light bulbs that contain mercury. Larger trash such as discarded appliances can present physical barriers to natural stream flow, causing physical impacts such as bank erosion. From a management perspective, persistence and accumulation of trash in a waterbody are of particular concern, and signify a priority area for prevention of trash discharges. Also of concern are trash "hotspots" where illegal dumping, littering, or accumulation of trash occurs.

Rapid Trash Assessment. Trash assessment includes a visual survey of the waterbody (e.g., stream bed and banks) and adjacent areas from which trash elements can be carried to the waterbody by wind, water, or gravity. The delineation of these adjacent areas is site-specific and requires some judgment and documentation. The rapid trash assessment worksheet is designed to represent the range of effects that trash has on the physical, biological, and chemical integrity of water bodies, in accordance with the goals of the Clean Water Act and the California Water Code. The worksheet also provides a record for evaluation of the management of trash discharges, by documenting sites that receive direct discharges (i.e., dumping or chronic littering) and those that accumulate trash from upstream locations.

Trash Characteristics of Concern. For aquatic life, buoyant (floatable) elements tend to be more harmful than settleable elements, due to their ability to be transported throughout the waterbody and ultimately to the marine environment. Persistent elements such as plastics, synthetic rubber and synthetic cloth tend to be more harmful than degradable elements such as paper, which can rip and biodegrade relatively quickly. Glass, foamed plastic and metal are less persistent, even though they are not biodegradable, because wave action and rusting can cause them to break into smaller pieces. Natural rubber and cloth can degrade but not as quickly as paper (U.S. EPA, 2002). Smaller elements such as plastic resin pellets (a by-product of plastic manufacturing) and cigarette butts are often more harmful to aquatic life than larger elements, since they can be ingested by a larger number of smaller organisms which can then suffer malnutrition or internal injuries. Larger plastic elements such as plastic grocery bags are also harmful to larger aquatic life such as sea turtles, which can mistake the trash for floating prey and ingest it, leading to starvation or suffocation. Floating debris that is not trapped and removed will eventually end up on the beaches or in the open ocean, repelling visitors and residents from the beaches and degrading coastal waters.

Trash in water bodies can threaten the health of people that use them for wading or swimming. Of particular concern are the bacteria and viruses associated with diapers, medical waste (e.g., used hypodermic needles and pipettes), and human or pet waste. Additionally, broken glass or sharp metal fragments in streams can cause puncture or laceration injuries. Such injuries can then expose a person's bloodstream to microbes in the stream's water that may cause illness. Additionally, some trash items such as containers or tires can pond water and support mosquito production and associated risks of diseases like encephalitis and the West Nile virus.

Leaf litter is trash when there is evidence of dumping. Leaves and pine needles in streams provide a natural source of food for organisms, but excessive levels of leaves, due to human influence, can cause nutrient imbalance and oxygen depletion in streams, to the detriment of the aquatic ecosystem. Clumps of leaf litter and yard waste from trash bags should be treated as trash in the water quality assessment, and not confused with natural inputs of leaves to streams. If there is a question in the field, check the type of leaf to confirm it comes from a nearby riparian tree. In some instances, leaf litter may be trash if it originates from dense ornamental stands of nearby human planted trees that are overloading the stream's assimilative capacity for leaf inputs. Other biodegradable trash, such as food waste, also exerts a demand on dissolved oxygen, but aquatic life is unlikely to be adversely affected unless the dumping of food waste is substantial and persistent at a given location.

Wildlife impacts due to trash occur in creeks, lakes, estuaries, and ultimately the ocean. The two primary problems that trash poses to wildlife are entanglement and ingestion. Marine mammals, turtles, birds, fish, and crustaceans all have been affected by entanglement in or ingestion of floatable debris. Many of the species most vulnerable to the problems of floatable debris are endangered or threatened.

Entanglement results when an animal becomes encircled or ensnared by debris. It can occur accidentally or when the animal is attracted to the debris as part of its normal behavior or out of curiosity. Entanglement is harmful to wildlife for several reasons. Not only can it cause wounds that can lead to infections or loss of limbs, but it can also cause strangulation or suffocation. In addition, entanglement can impair an animal's ability to swim, which can result in drowning or difficulty in moving about, finding food, and escaping predators (U.S. EPA, 2001).

Ingestion occurs when an animal swallows floatable debris. It sometimes occurs accidentally, but usually animals feed on debris because it looks like food, for instance plastic bags appearing like jellyfish, a prey item of sea turtles. Ingestion can lead to starvation or malnutrition if the ingested items block the intestinal tract, preventing digestion, or accumulate in the digestive tract, making the animal feel "full" and lessening its desire to feed. Ingestion of sharp objects can damage the mouth, digestive tract and/or stomach lining and cause infection or pain. Ingested items can also block air passages and prevent breathing, thereby causing death (U.S. EPA, 2001).

Common settled debris includes glass, cigarettes, rubber, construction debris and more. Settleables are a problem for bottom feeders and dwellers and can contribute to sediment contamination. Larger settleable items such as automobiles, shopping carts and furniture can redirect stream flow and destabilize the channel.

In conclusion, trash in water bodies can affect humans, fish, and wildlife in a number of adverse ways. Not all water quality effects of trash are the same in severity or duration, and the rapid assessment methodology was designed to reflect the range of trash impacts to aquatic life, public health, and aesthetic enjoyment. When evaluating the water quality effects of trash and conducting a rapid assessment, remember to evaluate individual items and their buoyancy, degradability, size, potential health hazard, and potential hazards to fish and wildlife, and select your scores accordingly.

References:
U.S. Environmental Protection Agency, 2001. Draft Assessing and Monitoring Floatable Debris.

U.S. Environmental Protection Agency, 2002. The Definition, Characterization and Sources of Marine Debris Unit 1 of Turning the Tide on Trash, a Learning Guide on Marine Debris.

RAPID TRASH ASSESSMENT WORKSHEET

Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board

WATERSHED/STREAM: ______________________ DATE/TIME: __________________
MONITORING GROUP, STAFF: _________________ SAMPLE ID NO. ________________
SITE DESCRIPTION (Station Name, No., etc.): ______________________________

	CONDITION CATEGORY			
Trash Assessment Parameter	**Optimal**	**Sub optimal**	**Marginal**	**Poor**
1. Level of Trash	On first glance, no trash visible; little or no trash evident when streambed and streambanks are closely examined for litter and debris, for instance by looking under leaves.	On first glance, little or no trash visible; after close inspection small levels of trash evident in streambank and streambed	Trash is evident in low to medium levels on first glance. Stream-bank surfaces and immediate riparian zone contain litter and debris. Evidence of site being used by people: scattered cans, bottles, blankets, and/or clothing	Trash distracts the eye on first glance. Streambank surfaces and immediate riparian zone contain substantial levels of litter and debris Evidence of site being used frequently by people: many cans & bottles, food wrappers, manmade shelters, blankets, and/or piles of clothing
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Actual Number of Trash Items Found	0 to 10 trash items based on a rapid survey of a 100-foot stream reach.	10 to 50 trash items based on a rapid survey of a 100-foot stream reach.	50 to 100 trash items based on a rapid survey of a 100-foot stream reach	Over 100 trash items based on a rapid survey of a 100-foot stream reach
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Threat to Aquatic Life	Trash, if any, is mostly paper or wood products or other biodegradable materials. Note: A large amount of rapidly biodegradable material like food waste creates high oxygen demand, and should not be scored as optimal.	Little or no (<10 pieces) persistent, buoyant, and small litter or debris. Presence of settleable, degradable, and non-toxic debris such as wood, glass, metal, and degradable plastics such as foamed plastics	Medium prevalence (10-50 pieces) of persistent (plastic, synthetic rubber or cloth), toxic, buoyant, and small litter such as plastic bags; pellets; cigarette butts, large deposits of settleable debris such as glass or metal, and any evidence of small clumps of deposited yard waste or leaf litter.	Large amount (>50 pieces) of persistent (plastic, synthetic rubber or cloth), toxic, buoyant, and small (transportable) trash such as cigarette butts; plastic bags, plastic pellets; batteries or other toxic substances; and large clumps of yard waste or dumped leaf litter
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Threat to Human Health	Observable trash contains no evidence of bacteria or virus hazards such as medical waste, diapers, pet or human waste, no evidence of toxic substances such as pesticides or batteries, no ponded water for mosquito production & no evidence of puncture or laceration hazards associated with the observed litter or debris	No medical waste or sources of toxic substances, but any presence (<10 pieces) of puncture or laceration hazards such as broken glass and metal debris Or presence of ponded water in trash items such as tires or containers that could facilitate mosquito production	Presence of **one** of the following: hypodermic needles, pipettes, or other medical waste , any used diapers or pet waste within the stream channel or where runoff could carry materials to waterbody, any toxic substance such as pesticides, batteries, or fluorescent light bulbs (mercury), medium prevalence (10-50 pieces) of puncture hazards	Presence of **more than one** of the item categories described previously in the marginal condition category, or high prevalence of any one item (e g greater than 50 puncture or laceration hazards)

RAPID TRASH ASSESSMENT WORKSHEET

Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board

	CONDITION CATEGORY			
Trash Assessment Parameter	**Optimal**	**Sub optimal**	**Marginal**	**Poor**
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Illegal Dumping and Littering	D: No evidence of illegal dumping L: Any observed trash is incidental litter (less than 5 items) or carried downstream from another location.	D: Some evidence of illegal dumping, such as a sign prohibiting dumping along with observed garbage bags of material. Limited vehicular access limits the amount of potential dumping, or material dumped is diffuse paper-based debris (e.g., convenience stores or fast food). L: Some evidence of litter within creek and banks originating from adjacent land uses (<10 items)	D: Presence of **one** of the following: furniture, appliances, or bags of garbage or yard waste, coupled with vehicular access that facilitates in-and-out dumping of materials to avoid landfill costs. L: Prevalent (10-50 items) in-stream or shoreline littering that appears to originate from adjacent land uses	D: Evidence of chronic dumping, with **more than one** of the following items: furniture, appliances, shopping carts, garbage bags, or yard waste. Easy vehicular access for in-and-out dumping of materials to avoid landfill costs. L: Vary large amount (>50 items) of litter within creek and banks that appear to originate from adjacent land uses.
D-SCORE	10 9	8 7 6	5 4 3	2 1 0
L-SCORE	10 9	8 7 6	5 4 3	2 1 0
6. Accumulation of Trash	There does not appear to be a problem with trash accumulation from downstream transport. Observable trash, if any, appears to have been directly deposited at the stream location.	Some evidence that litter and debris have been transported from upstream areas to the location. Less than 10 trash items have been transported from upstream locations, based on evidence such as silt marks, faded colors or location near high water marks	10 to 50 items of observable trash are carried to the location from upstream, as evidenced by its location near high water marks and siltation marks on the debris.	Trash appears to have accumulated in substantial quantities at the location based on delivery from upstream areas, and is in various states of degradation based on its persistence in the waterbody. Over 50 items of observable trash have been carried to the location from upstream
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Total Score ______________

SITE DEFINITION:

UPPER/LOWER BOUNDARIES OF REACH: ____________________________________

HIGH WATER LINE: ____________________________________

UPPER EXTENT OF BANKS OR SHORE: ____________________________________

____

NOTES:

____

____

____

____

____

____

____

RAPID TRASH ASSESSMENT WORKSHEET

Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board

<u>**TRASH ITEM TALLY** (Tally with (|) if found below high water line, and (•) if above)</u>

PLASTIC	**METAL**
Plastic Bags	Aluminum Foil
Plastic Bottles	Aluminum or Steel Cans
Plastic Bottle Caps	Bottle Caps
Plastic Cup Lid/Straw	Metal Pipe Segments
Plastic Pipe Segments	Auto Parts (specify below)
Plastic Six-Pack Rings	Wire (barb, chicken wire etc.)
Plastic Wrapper	Metal Object
Soft Plastic Pieces	**LARGE (specify below)**
Hard Plastic Pieces	Appliances
Styrofoam cups pieces	Furniture
Styrofoam Pellets	Garbage Bags of Trash
Fishing Line	Tires
Tarp	Shopping Carts
Other (write-in)	Other (write-in)
BIOHAZARD	**TOXIC**
Human Waste/Diapers	Chemical Containers
Pet Waste	Oil/Surfactant on Water
Syringes or Pipettes	Spray Paint Cans
Dead Animals	Lighters
Other (write-in)	Small Batteries
CONSTRUCTION DEBRIS	Vehicle Batteries
Concrete (not placed)	Other (write-in)
Rebar	**BIODEGRADABLE**
Bricks	Paper
Wood Debris	Cardboard
Other (write-in)	Food Waste
MISCELLANEOUS	Yard Waste (incl. trees)
Synthetic Rubber	Leaf Litter Piles
Foam Rubber	Other (write-in)
Balloons	**GLASS**
Ceramic pots/shards	Glass bottles
Hose Pieces	Glass pieces
Cigarette Butts	**FABRIC AND CLOTH**
Golf Balls	Synthetic Fabric
Tennis Balls	Natural Fabric (cotton, wool)
Other (write-in)	Other (write-in)

SPECIFIC DESCRIPTION OF ITEMS FOUND (if any):

____

____

____

____

____

____

**SCVURPPP Pilot Implementation and Testing
Of the RWQCB Rapid Trash Assessment**

INTRODUCTION

Program staff implemented and tested the Regional Water Quality Control Board's (RWQCB) *Rapid Trash Assessment Worksheet* at nine stream locations in Santa Clara and San Mateo Counties. Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and San Mateo Countywide Pollution Prevention Program (STOPPP) are collaborating to determine the utility of the approach for performing the following functions:

- Document baseline levels of trash in creeks
- Identify sources of trash and appropriate control measures to reduce trash
- Evaluate effectiveness of trash management practices
- Assess all creeks in the SCVURPPP jurisdiction for trash
- Assess impairment of beneficial uses from trash

Results of the pilot assessment were presented by Program staff at the September 25th SCVURPPP Trash Ad Hoc Task Group (AHTG) and at the October 2nd BASMAA Monitoring Committee meeting. Comments from the Trash AHTG were compiled and incorporated into the discussion section of this memorandum. The current draft of the trash assessment technical memorandum was approved by the AHTG at the November 4th Trash AHTG meeting.

Development and implementation of trash assessment protocols is one component of the SCVURPPP Trash Work Plan. Further development of the trash assessment protocols adopted by SCVURPPP will be based upon the recommendations included in this memorandum and comments from Regional Board staff and members of the BASMAA Monitoring Committee. The final draft technical memorandum will be submitted with the Work Plan to the Regional Board on March 1st, 2003.

BACKGROUND

A November 2001 Regional Board staff report proposes changes to the 1998 303(d) list of impaired water bodies in the Bay area. The staff report states there "are excessive levels of trash in virtually all urbanized waterways of the San Francisco Bay Region." However, listing these waterways as impaired by trash is not proposed due to a lack of consistent assessment methodology.

Instead, the staff report proposes placing all Bay area urban creeks, lakes, and shorelines on a preliminary or "watch" list due to the threat of trash to impair water quality. It states that between now and the next 303(d) listing cycle, municipalities will be expected to assess trash impairments in their jurisdictions, as documented by storm water agencies in annual reports to the Regional Board. The report recommends that the approach mirror the standard TMDL approach of defining the problem, identifying the sources through monitoring or existing information, and developing a program of action to address the principle sources. Regional Board staff will review this specific information in the next listing cycle and determine whether specific water bodies warrant 303(d) listing for trash, and note the existence of relatively clean urban streams

附件四

SCVURPKPPP Pilot Implementation and Testing Of the RWQCB Rapid Trash Assessment

**SCVURPPP Pilot Implementation and Testing
Of the RWQCB Rapid Trash Assessment**

INTRODUCTION

Program staff implemented and tested the Regional Water Quality Control Board's (RWQCB) *Rapid Trash Assessment Worksheet* at nine stream locations in Santa Clara and San Mateo Counties. Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and San Mateo Countywide Pollution Prevention Program (STOPPP) are collaborating to determine the utility of the approach for performing the following functions:

- Document baseline levels of trash in creeks
- Identify sources of trash and appropriate control measures to reduce trash
- Evaluate effectiveness of trash management practices
- Assess all creeks in the SCVURPPP jurisdiction for trash
- Assess impairment of beneficial uses from trash

Results of the pilot assessment were presented by Program staff at the September 25th SCVURPPP Trash Ad Hoc Task Group (AHTG) and at the October 2nd BASMAA Monitoring Committee meeting. Comments from the Trash AHTG were compiled and incorporated into the discussion section of this memorandum. The current draft of the trash assessment technical memorandum was approved by the AHTG at the November 4th Trash AHTG meeting.

Development and implementation of trash assessment protocols is one component of the SCVURPPP Trash Work Plan. Further development of the trash assessment protocols adopted by SCVURPPP will be based upon the recommendations included in this memorandum and comments from Regional Board staff and members of the BASMAA Monitoring Committee. The final draft technical memorandum will be submitted with the Work Plan to the Regional Board on March 1st, 2003.

BACKGROUND

A November 2001 Regional Board staff report proposes changes to the 1998 303(d) list of impaired water bodies in the Bay area. The staff report states there "are excessive levels of trash in virtually all urbanized waterways of the San Francisco Bay Region." However, listing these waterways as impaired by trash is not proposed due to a lack of consistent assessment methodology.

Instead, the staff report proposes placing all Bay area urban creeks, lakes, and shorelines on a preliminary or "watch" list due to the threat of trash to impair water quality. It states that between now and the next 303(d) listing cycle, municipalities will be expected to assess trash impairments in their jurisdictions, as documented by storm water agencies in annual reports to the Regional Board. The report recommends that the approach mirror the standard TMDL approach of defining the problem, identifying the sources through monitoring or existing information, and developing a program of action to address the principle sources. Regional Board staff will review this specific information in the next listing cycle and determine whether specific water bodies warrant 303(d) listing for trash, and note the existence of relatively clean urban streams.

METHODS

The RWQCB Rapid Trash Assessment Version 6.0 was released to the public on September 25, 2002. The assessment was designed for several purposes, including ambient monitoring, evaluation of management actions, and evaluation of the effects of public access to trash condition of creeks. The RWQCB began implementing the trash assessment in summer of 2002 as part of their Surface Water Ambient Monitoring Program's Regional Monitoring and Assessment Strategy (SWAMP/RMAS).

The assessment protocol includes identification and enumeration of all trash items that occur below high water line and along stream banks within a 100-foot section of stream. The second part of the RWQCB protocol includes determination of condition for six assessment parameters (scores 0-20, higher score = less trash) using the narrative parameter descriptions provided in the assessment worksheet. Program staff attended a training session on these protocols given by RWQCB staff. In addition to implementing the assessment approach, Program staff took digital photographs at each site to determine if photo documentation could accurately depict level of trash and potential impairment.

The pilot testing of the RWQCB's approach did not include implementing the assessment for different seasons to determine temporal variation of trash condition at individual sites. The pilot assessment was conducted in the fall to capture levels of trash in the creeks prior to winter rains, and before the national trash cleanup event that occurred on September 21st 2002.

Assessments were completed over a two-day period in September 2002 at five stream locations within San Pedro Creek (Figure 1), a coastal watershed in San Mateo County, and four stream locations in Coyote Creek watershed (Figure 2), which is located in the eastern portion of the Santa Clara Valley and drains into the South Bay. The assessment locations were based on several factors including known hot spots, land use type (residential, commercial, open space) and stream size. Creek segments in Upper Penitencia (total =3) and San Pedro Creek (total = 5) were selected at different points in each respective watershed to represent varying degrees of urbanization, i.e., sites at the lower, middle and upper sections of the urbanized portion were surveyed within each watershed. One site on Coyote Creek was sampled to identify the feasibility of this assessment approach in larger streams.

RESULTS

Individual parameters scores, total scores and the number of major trash item types for each assessment site are provided in Tables 1 and 2. Major findings include:

1) The areas previously identified as hot spots had the worst scores within each watershed. The flea market site, although not previously identified as a hot spot, appeared to have a chronic trash problem and should be considered a hot spot. The two highest scores were at the upper sites of each watershed, toward the edge of the urban boundary.

2) Total scores decreased and total trash items increased in a downstream direction. Most of the individual assessment parameter scores also decreased in a downstream direction, with the exception of the human health parameter, which was consistently rated as sub-optimal at all but two sites

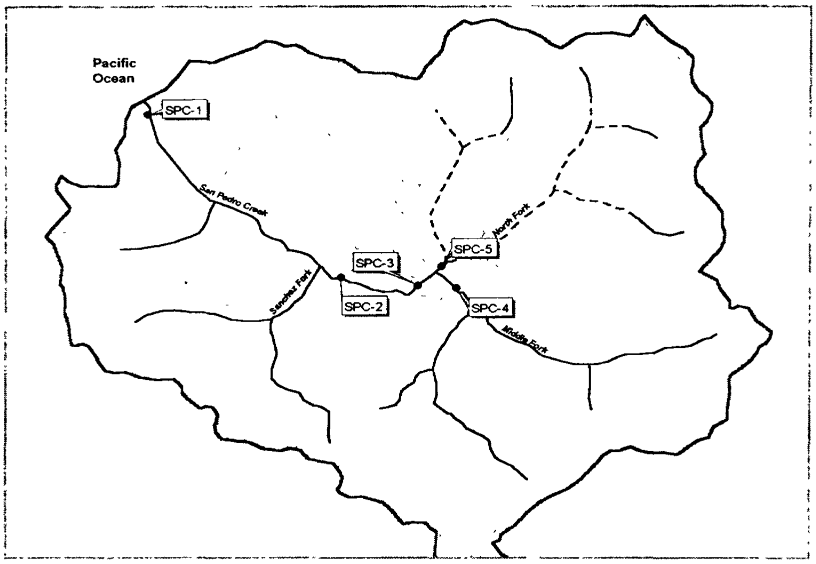


Figure 1. Location of pilot trash assessments conducted in San Pedro Creek.

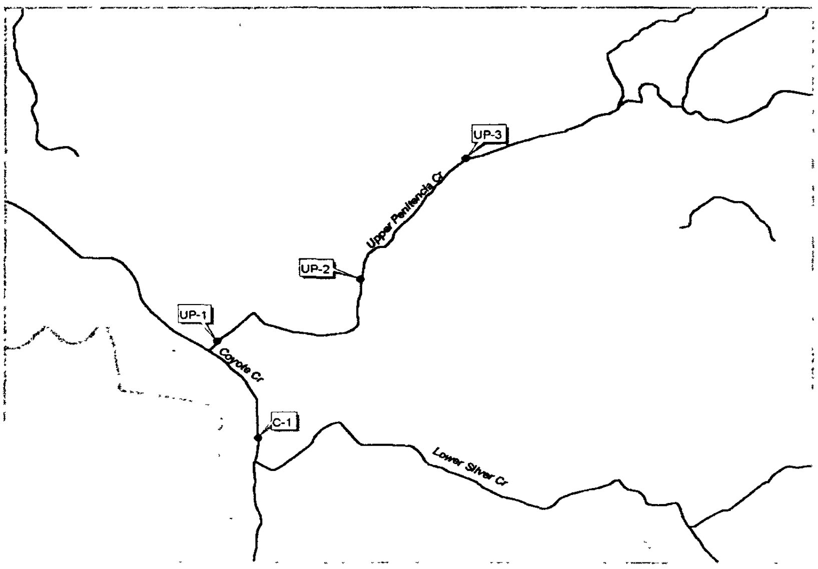


Figure 2. Location of pilot trash assessments conducted in Upper Penitencia and Coyote Creek.

3) The survey worked best in Upper Penitencia and San Pedro Creeks because all areas of the stream habitat were accessible and generally visible. The assessment at the site on Coyote Creek was less effective because the creek was too deep in some areas and the visibility too poor to accurately identify all trash items. There were generally no problems identifying trash along the stream banks, although there was difficulty in some instances of identifying the upper boundary (see # 5).

4) Digital photographs provided insufficient details to identify level of trash, estimate threats to water quality, or potential sources of trash. The relative number of trash items and types of trash are not clearly distinguishable. These results were consistent with earlier RWQCB evaluation. The photos may be useful for identifying benchmarks that define site boundaries and for documenting the general conditions of the site.

5) Using slightly different definitions for the stream bank boundary can have significant impact on the results. Incorporating trash items along the edge of upper right bank adjacent to a parking lot (at lowest site in San Pedro Creek) resulted in decreasing the total score from 74 to 30. Integrating trash for the upper section of streambank was questionable in this case because dense riparian vegetation appeared to prevent trash from entering the creek. There was minimal evidence of trash in the creek.

6) The lower site of San Pedro Creek and Upper Penitencia Creek (flea market) were cleaned up for trash shortly after the assessment. If the assessment had been repeated after the cleanup, the trash scores would have been much improved.

7) Eight of nine sites were rated poor for quantity of trash. In contrast, half of these eight sites were qualitatively rated sub-optimal (visual estimation of trash problem). As a result, conditions for qualitative and quantitative parameters were not very correlated.

8) The most common trash items for all sites were plastic (primarily bags, bottles and wrappers), biodegradable (mostly paper), and metal (aluminum foil wrappers and cans). Trash items were more prevalent below the water line, with the exception of paper, cigarette butts and glass bottles, which were more common on the stream banks.

9) The trash items found that were considered threats to aquatic health were typically plastic (bags, bottles, wrappers) and other buoyant items (styrofoam and cigarette butts). The condition rating for aquatic health parameter was largely based on the relative number of these items found (e.g., low, medium prevalence, large amount), regardless if the plastic items were in the creek or on the bank. The scores typically decreased in the downstream direction.

10) There were few trash items found considered to be threats to human health. The most common were sharp objects, such as glass and jagged metal. There were animal feces and diapers found on the banks of two sites. The condition for this parameter was never optimal because there was always glass found on-site; five of the nine sites were rated sub-optimal due to presence of glass. There were no spatial trends observed for this parameter.

11) Dumping and littering appear to be a major problem for some sites we assessed. All four sites that were rated poor for this parameter had the lowest total scores and the highest number of trash items. Three of these sites were commercial and one was

Table 1. Rapid trash assessment results from two watersheds in Santa Clara and San Mateo County. Trash assessment parameter scores are selected between 0-20, with low numbers representing poor conditions. Similarly, low total score represents poor conditions.

Location Description	Site Id	Land use	Date	Trash Assessment Parameter Scores: Qual.	Quant.	Aquatic Life	Human health	Dump/ Litter	Accum	Total Score
Santa Clara County (Upper Penitencia Creek)										
Fleamarket	UP-1	Commercial	9/12/02	6	0	5	16	5	7	**39**
Penitencia Park (lower)	UP-2	Residential/park	9/12/02	13	4	11	3	12	10	**53**
Penitencia Park (upper)	UP-3	Residential/park	9/12/02	15	5	15	15	14	13	**77**
Watson Park (Coyote)*	C-1	Undeveloped Park	9/12/02	8	2	4	12	1	6	**33**
San Mateo County (San Pedro Creek)										
Above Pacifica Beach*	SPC-1	Commercial	9/20/02	6	1	4	5	5	9	**30**
Behind Sanchez Art Center	SPC-2	Residential	9/20/02	12	3	6	15	15	4	**55**
Below Linda M ar Bridge	SPC-3	Residential	9/20/02	12	3	8	15	14	5	**57**
Above Oddstad Bridge	SPC-4	Residential/park	9/20/02	15	6	14	15	13	19	**82**
Behind Shopping Center (North Fork)*	SPC-5	Commercial	9/20/02	1	0	1	11	5	1	**19**

Table 2. Total number of items from each major category of trash tallied in trash assessments for nine locations in Santa Clara and San Mateo County. Stream location "A" and "B" represents above and below, respectively, high water line.

Site Id	Plastic		Biohazard		Const Debris		Misc.		Metal		Large Items		Toxic		Bio.		Glass		Fabric		Total #
Location	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	
UP-1	77	85	0	0	3	0	2	13	10	4	0	0	0	0	35	36	0	0	1	4	**270**
UP-2	22	7	2	0	5	0	2	0	14	0	0	0	1	0	6	6	6	0	2	1	**74**
UP-3	17	13	0	0	0	1	2	0	1	4	0	0	0	0	7	12	2	1	1	0	**61**
C-1	35	17	0	0	4	0	1	0	10	2	20	0	0	0	18	26	3	3	2	2	**143**
SPC-1	32	46	0	1	2	0	1	61	4	6	0	0	0	0	4	64	0	1	0	1	**223**
SPC-2	66	29	0	0	11	0	4	0	14	3	1	0	0	0	3	6	1	1	14	3	**156**
SPC-3	80	10	0	0	8	0	14	1	11	0	0	0	0	0	4	0	2	0	1	1	**132**
SPC-4	5	9	0	0	4	1	1	0	9	2	0	1	0	0	0	2	2	9	1	1	**47**
SPC-5	205	31	0	0	11	17	14	3	29	11	4	1	0	0	19	4	0	11	2	4	**366**
Total	539	247	2	1	48	19	41	78	102	32	25	2	1	0	96	156	16	26	24	17	**1472**

undeveloped parkland, which had low scores due to dumping. A majority of the trash observed was from littering, not dumping.

12) Accumulation of trash generally increases in the downstream direction as expected, with the exception of the lower site on San Pedro Creek, which had very little accumulated trash. This may be due to yearly trash clean up events. Only two of nine sites had less than five accumulated trash items; the rest of the sites were marginal or poor.

DISCUSSION

The Trash AHTG evaluated the results of the pilot assessment and the overall approach used in the RWQCB protocols. The AHTG addressed the following questions to evaluate the utility of the RWQCB's assessment protocols for assessing trash in SCVURPPP streams:

- What role should the RWQCB's protocol play in assessing trash? (e.g., identify baseline levels of trash in urban creeks; document status and trends; identify trash sources; evaluate effectiveness of BMPs).
- How feasible is the approach to assess all urban creeks in SCVURPPP jurisdiction?
- Can the results be used to assess potential impairment to beneficial uses?
- What refinements would enhance utility of assessment approach?

Role of Trash Assessment for SCVURPPP

The Trash AHTG agreed that the RWQCB trash assessment could be used at specific reaches to establish baseline levels of trash. Future assessments could be conducted at these sites using the same protocols to document status and trends or to help evaluate the effectiveness of targeted BMPs. In addition, the assessment results may assist in the identification of potential sources of trash and appropriate BMPs to implement. Overall, the protocols would be useful in prioritizing and implementing management activities and measuring the effectiveness of these actions.

One limitation identified by the AHTG is related to implementing the RWQCB protocols to characterize trash conditions for entire water bodies or subwatersheds. The level of trash within a single waterbody is assumed to be highly variable due to changes in land use, accessibility, size of the watershed, and channel characteristics (e.g., gradient, stream vegetation). Several 100-foot sections of creek would need to be assessed to measure the range of trash conditions found within a waterbody. Assessing some sections of creek and extrapolating the information to larger areas, however, could lead to misinterpretation of the results and potential listing for an entire waterbody based on data collected at a few reaches. Further discussion on the feasibility of using the RWQCB protocols to assess trash for all creeks within SCVURPPP jurisdiction is provided below.

The Trash AHTG agreed that the RWQCB protocols provide a standardized approach to assess trash, which could be used on a regional basis. Collaboration with other storm water programs and SWAMP using the same protocols would provide a larger data set for more detailed data analyses, which may include identifying relationships between trash condition and land use types. These relationships would assist managers in identifying potential trash problem areas and aid in selecting appropriate assessment locations. In addition, compilation of assessment data taken in urban streams would be useful for statistically identifying thresholds used in the condition categories for each of the assessment parameter (see recommendation section below). Program staff has started compiling trash assessment data gathered from Alameda County Cleanwater Program and Regional Board efforts.

Feasibility of Assessing all SCVURPPP Creeks

The Trash AHTG believed it was not feasible or cost-effective to use the RWQCB protocols to assess all creeks within the SCVURPPP jurisdiction. High variability of trash conditions would be expected within sections of urban creeks. In addition, an estimation of trash levels for a single creek would require numerous assessments. It is more cost effective to assess sites in areas that are impacted or in land uses that are associated with litter or illegal dumping and monitor these sites over time to determine trends or evaluate the effectiveness of BMPs. The Trash AHTG agreed that a decision to spend resources on conducting trash assessments for all creeks in their jurisdiction needs to be weighed with efforts to resolve problems that have already been identified. For example, schools and commercial areas are land uses that are often associated with trash-impacted areas. The Trash AHTG will identify a process for prioritizing creek segments (potentially on land use) and implementing trash assessments as a task in the Trash Work Plan. The proper entity (e.g., municipality/agency staff or volunteer citizen group) to conduct trash assessments will also be determined as a task in the Work Plan.

Utility of Assessment to Measure Potential Impairment

The trash AHTG identified several limitations of the protocol in linking trash assessment results with potential impairment to beneficial uses. First, there is no clear linkage between type of trash items or number of trash items in a reach to beneficial use impairment. There are no established criteria or threshold values of specific trash items that can be used to estimate the relative impairment to most beneficial uses. An exception may be using both quantitative and qualitative assessment parameters to evaluate the aesthetic quality of streams for REC1 and REC2 beneficial uses. Two parameters (aquatic and human health) identify specific trash items that may affect beneficial use attainment, but more than the presence of these items is needed to determine the level of impairment. For example, there is no method to determine how many small persistent trash items (e.g., styrofoam pellets) are necessary to impact the aquatic biota. In addition, the link between human health and the presence of human diapers or animal feces within a 100-foot section of stream has not been clearly established. These trash items may not have direct contact with the water and in some cases, may not even contain human pathogens. Furthermore, the threat to human health ranking does not take into account the potential level of public exposure. Exposure to contaminated water or sharp objects (e.g., glass and metal) is dependent on the level of accessibility to a creek (e.g., fences limit access to creeks) and creek conditions (e.g., depth of water).

Recommendations for Refining Protocols

The RWQCB protocols were designed to assess both rural and urban stream conditions. The threshold values used to identify conditions for some of the assessment parameters may be too conservative and not adequately represent the range of conditions typically found in urban streams. As a result, most urban creek segments are likely to fall into the poor or marginal categories. Ubiquitous low scores for all urban creeks would not provide adequate resolution to distinguish spatial or temporal variation in trash conditions.

The RWQCB protocols were developed with the intention to assist in management decisions, such as source identification. The utility for the protocols to identify trash sources could be enhanced if litter and illegal dumping were separated into different parameters to better assist managers in the identification of appropriate BMPs to reduce the trash. In addition, new trash item categories should be added to enhance evaluation of BMP effectiveness, such as recycling programs. For example, tallying aluminum cans and plastic bottles that are labeled with California Redemption Value (CRV) symbol, along with non-CRV cans and bottles can help determine if recycling programs are effective at reducing trash in creeks.

Table 3 lists the limitations of the RWQCB protocols for conducting trash assessments of creeks in SCVURPPP jurisdiction and provides recommended revisions. The Trash AHTG will coordinate all recommended revisions to the protocols with other stormwater programs, BASMAA Monitoring Committee and the RWQCB staff in order to develop a standardized approach for conducting trash assessments on a regional basis. The assessment approach should be evaluated in the future for continuous improvement as additional assessment results become available.

Table 3. Recommended Revisions to Assessment Protocol

Trash Assessment Parameter	**Limitation**	**Recommendation**
Actual Number of Trash Items	Numerical thresholds used to rate categories too conservative and not representative for range of conditions in urban streams	Compile additional assessment results from urban streams and statistically compute ranges.
	Difficult to evaluate BMP effectiveness for existing trash item categories	Include additional categories useful for evaluating BMP effectiveness (e.g., distinction between recyclable and non-recyclable cans and bottles)
Threat to Aquatic Life	Subjective rating (little, medium, large) for number of persistent trash items may not provide consistent results.	Compile additional assessment results for specific trash items found in urban streams and statistically compute ranges.
	Equal weighing for trash above and below water line.	Place greater weight on trash below water line. Define water line mark as the bankfull channel.
Threat to Human Health	Human health threats are determined only by presence of specified trash items, not on potential for exposure.	Include additional rating for potential risk of exposure (e.g., public access: good/poor; wadable habitat: yes/no).
Illegal dumping and Littering	Doesn't provide a mechanism to distinguish two different trash sources.	Separate into two separate categories to enhance distinction of trash sources.

Trash Assessment Parameter	Limitation	Recommendation
Illegal dumping and Littering	Litter categories do not address accumulation from adjacent land uses that result from wind.	Include narrative description to rate wind accumulated litter from adjacent land uses; expand its definition of "shoreline littering" to include "litter within creek and banks that appear to originate from adjacent land uses."
Accumulation of trash ·	Numerical thresholds used to rate categories not representative for range of conditions in urban streams.	Compile additional assessment results from urban streams and statistically compute ranges.

Next Steps

- Obtain comments from members of BASMAA Monitoring Committee and RWQCB. Comments need to be sent to Program staff no later than December 2nd, 2002.
- Trash AHTG approves final draft trash assessment technical memorandum.
- Send final draft technical memorandum to SCVURPPP Management Committee.
- Attach to SCVURPPP Work Plan for March 1, 2003 submittal to Regional Board.

附　件　五

SURFACE WATER AMBIENT MONITORING PROGRAM

SWAMP

SURFACE WATER AMBIENT MONITORING PROGRAM

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
SAN FRANCISCO BAY REGION
MARCH 5, 2002

Land managers, environmentalists, industries, cities, and farmers all agree that the nine California Regional Water Quality Control Boards need to set up water quality monitoring programs so that their regulatory decisions are based on the best available science. Through the urging of a public advisory group representing all of these perspectives, the state began the Surface Water Ambient Monitoring Program (SWAMP) in 2000. The San Francisco Bay Regional Water Quality Control Board (Water Board) is in the second year of conducting this statewide monitoring program, measuring water quality indicators in creeks, lakes, reservoirs, and bays of the San Francisco Bay Region.

The Water Board intends to use this new source of funding to do a better job of identifying places in the region where improvements are scientifically warranted, and also to highlight areas where water quality is exceptional. The Water Board has a legal obligation to assess the physical, chemical, and biological status of waters and report to Congress every 2 to 4 years, with or without scientific information. Additionally the Water Board needs to evaluate the success of water quality control programs such as permits for discharges of treated wastewater and grants for stream restoration.

<u>Monitoring Streams and Watersheds</u>
Unfortunately, in watersheds where the Water Board does not issue very many discharge permits, there is very little information available to make these mandatory assessments. Therefore, we have decided to focus the SWAMP program mostly on the wadeable streams of the Bay Area. Access to streambeds is often a limiting factor for field staff. The Water Board wants to make decisions based on scientific investigation and high quality data. In order to achieve this goal, the Water Board needs to collect water, sediment, and biological samples throughout its jurisdiction to understand baseline conditions (how things are now), and understand natural variability and effects of land use on water quality. To collect these samples, the Water Board needs assistance from public and private landowners and managers, primarily in the form of *access*.

The Act for the Admission of California into the United States includes the statement that "all the navigable waters within the said State shall be common highways, and forever free…" This is but one expression of the law and countless court findings that the health of *all* water bodies are in the public interest, and that the state has sovereignty within these water bodies, even small streams. But accessing the state's water bodies often requires entering and crossing private property, and therefore the Water Board needs permission and cooperation from property owners to achieve its goals of science-based regulatory decision-making.

The Water Board prefers to make decisions based on best available science. Monitoring water quality can achieve this goal, if it answers questions, such as:

- Does the water, sediment, or fish tissue contain pollutants at levels that violate water quality standards?
- Are water quality objectives for dissolved oxygen, pH, ammonia, bacteria, and other parameters met in the water bodies?
- Is the water or sediment toxic to organisms?
- Does the water body support a reasonable level of biodiversity, or do disturbance-tolerant organisms dominate the biological community?
- What is the physical integrity of the water body, especially regarding flow, sediment, and fish habitat?

To achieve the goal of generating water quality information for all watersheds in the San Francisco Bay Region in the next 5 to10 years, the Water Board has proposed a rotating basin approach under the Regional Monitoring and Assessment Strategy (RMAS), posted on the website at www.swrcb.ca.gov/rwqcb2 under available documents. The region has been divided into 47 planning watersheds, based on hydrology. In any given *calendar year*, 3 to 12 watersheds (of about 50-100 square miles) will be targeted for monitoring by the Water Board, based on staffing and funding. Other watersheds under the RMAS are simultaneously addressed by local agencies or organizations using similar monitoring designs as the Water Board.

Monitoring Design

When the Water Board begins to work in a new watershed, the first task is to characterize and map the watershed drainage area, channel network, and general land uses. The Water Board is interested in the ways people use the waterbodies, such as for swimming, wading, fishing, drinking, agricultural use, and habitat for fish and wildlife. These uses are known as "beneficial uses" of waters. The beneficial uses and the general land uses, hydrology, geology and vegetation characteristics of a watershed will help guide what kind of questions that water quality, physical, and biological monitoring can answer. To implement the RMAS, the best monitoring locations (i.e., sites or stations) will be those that help answer a question about cause and effect – the cause of a particular discharge, land use, water use, restoration project, geologic formation, vegetation type, or channel morphology and its effect on water quality or aquatic biological integrity. It is also important to have a population of stations that may serve as reference sites, where water quality impacts from land uses are expected to be minimal, so that impacted sites are analyzed in the context of background natural factors. We never expect pristine conditions right where people live and work, but we are interested in using our regulatory and funding mechanisms to help improve water quality where possible, consistent with our mission to protect the waters of the state for their use and enjoyment by the people of the state.

Tier 1 and Tier 2 Sampling

Tier 1 includes more general measurements to be made at all selected sampling locations, allowing a screening-level assessment of physical, chemical, and biological integrity, and Tier 2 includes measurements to answer specific questions about certain land uses and the potential impairment of water quality.

Tier 1 measurements include general water quality, rapid bioassessment, and visual level of physical assessment. The California Stream Bioassessment Procedure includes sampling of stream macroinvertebrates (e.g., aquatic insects, crustaceans, mollusks, and worms) and a visual level of physical assessment. Tier 1 also includes general water quality parameters that can be measured using field probes. General water quality parameters are defined as temperature, electrical conductivity, dissolved oxygen, and pH, and will be monitored continuously where and when feasible, as available equipment allows.

More detailed Tier 2 monitoring, requiring the collection of a water, sediment, or tissue sample, is conducted at a subset of the Tier 1 sites. Parameters such as pathogen indicators, nutrients, toxic pollutants, and toxicity, will be pursued if land use, beneficial uses, previous data, or previous impairment findings suggest that there is a potential problem. Also, such analyses may be conducted in subsequent years if suggested by results of these initial screening studies.

The decision to measure one or all of the above Tier 2 parameters at a given sampling location is dependent on a number of factors, including (1) land use, (2) existing impairment listings, (3) beneficial uses, (4) available budget, (5) specific questions of water quality impact, (6) "control" sites that are presumably natural background, and (7) overall geographic balance for measurement of specific parameters.

A separate monitoring program is documenting bioaccumulative pollutant levels in fish tissue from commonly fished reservoirs throughout the region, in order to assess how safe it is to eat different fish species in these recreational areas.

The database to manage and analyze these data is in the set-up phase. Once the data are processed for quality control, they will be available on the statewide system. The time between sampling and availability of information is about one year or longer, due to the careful quality control and limited staff resources.

<u>Frequency and Timing of Monitoring</u>

Tier 1 general water quality monitoring will be conducted throughout the 9 to 12-month sampling period, consisting of continuous monitoring conducted strategically as available equipment allows. Typically the probe deployments are for two weeks, approximately 6 times at a given station over the calendar year, and collect readings every 15 minutes. Bioassessments will be conducted in the spring, as recommended by professional biologists, and preliminary visual physical assessments will be conducted at the same time. Digital photos will be taken during each Tier 1 water quality sampling event, and will document dynamic channel conditions and the level of trash at each sampling station.

Due to limited staff and analytical budget, and lack of site-specific knowledge of stream water quality, Tier 2 monitoring emphasizes spatial distribution at the expense of temporal distribution to screen for obvious departures from the norm. Frequency and timing of Tier 2 parameter suites is proposed to be conducted as follows:

- Nutrients: three sampling events during the year (wet weather, dry weather spring flows, and dry weather or late summer[1]) at several specific stations in a watershed, but not at all the sites where Tier 1 sampling is performed. Nutrient and conventional chemistry measurements include nitrogen, phosphorus, organic carbon, chlorophyll a, suspended sediments, total dissolved solids, etc.
- Pathogen Indicators: one to three sampling events during the year (wet weather, dry weather spring flows, and dry weather or late summer) at sites where the public has water contact, or where there are suspected or documented problems with animal facilities, community septic systems, or leaking sanitary sewer collection systems. Sampling timing is based on the beneficial use of concern (for shellfish, emphasis on wet weather sampling; for water contact, emphasis on dry weather sampling). A sampling event is five times over a 30-day period.
- Toxicity/Water: three sampling events during the year (runoff events, spring flow, and low-flow condition, and/or time of application of suspected chemical or pesticide) to perform 3-species screening test (algae, invertebrates, fish) on water samples to determine whether potential sources of toxicity (pesticide application or illicit discharges) are resulting in detectable in-stream toxicity. Stimulation of algal growth can signify elevated nutrients.
- Toxicity/Sediment: one sampling event during the year to perform freshwater sediment toxicity test (e.g., *Hyalella azteca*) at the lowest nontidal watershed sampling station.
- Contaminants (metals and organics): three sampling events during the year, concurrent with toxicity and/or nutrient sampling. The matrix to be sampled (water, sediment, tissue) will be considered on a pollutant-by-pollutant basis. At the bottom of the watershed, bivalves are deployed in bags for 30-days to measure accumulation of pollutants in tissues.
- Physical Assessment (measured) – Geomorphic measurements at selected sites within a watershed based on review of initial visual physical assessments, to be conducted when time is available, most likely during late summer.

Availability of Data

SWAMP is in its startup phases, especially with respect to data management and presentation. Because the Water Board is a public agency, the data will ultimately be available to anyone, but it will take time to assure its quality and to develop ways to efficiently deliver it to interested parties. We anticipate after sample collection, it will be about one year before data from a group of watersheds is available to the public. The Water Board will produce interpretive reports to help prevent miss-application of data. By using the rotating basin approach, no watersheds are singled out for scrutiny, and the data will be comparable across the region, from the Golden Gate to Altamont Pass, and

[1] Timing of Tier 2 monitoring is based on the seasonal hydrology of the San Francisco Bay Region, and will be conducted up to 3 times per year, corresponding to (1) wet weather, or periods of saturated soil runoff and higher flows, (2) spring flow period, when shallow groundwater is elevated due to previous rainfall and stream flow is elevated relative to dry weather periods, and (3) dry weather, typically in June or later, when perennial stream flows are generally contained in the low-flow channel. Specific parameters will be measured corresponding to periods within these "hydrologic regimes."

from Calistoga in the north to Morgan Hill in the south. The structure of this program should therefore allay concerns of cooperative landowners and managers, and if problems are identified, they can be assured of fair treatment in a public process the Water Board provides under law.

The Water Board is optimistic that by collecting different types of water quality indicators together, a more accurate picture of watershed health will emerge. We are not interested in making hasty decisions based on monitoring data, but wish to draw attention to areas where water quality is exceptional, or where improvements are needed to protect public health and the aquatic ecosystem. These goals will not be achieved without cooperation and assistance of public and private landowners and managers throughout the Bay Area.

The SWAMP Program Manager for the Water Board is Karen Taberski (ph. 510-622-2424, email kmt@rb2.swrcb.ca.gov). We are happy to answer questions about the program as it grows and matures, and to meet personally with local organizations and agencies to report on the status of monitoring designs and/or results in specific watersheds, as they become available.

California Regional Water Quality Control Board
San Francisco Bay Region
1515 Clay Street, Suite 1400
Oakland, CA 94612

附　件　六

Procedures and Protocols for Continuous Water Quality Monitoring

Procedures and Protocols for Continuous Water Quality Monitoring

San Francisco Bay Regional Water Quality Control Board

Surface Waters Ambient Monitoring Program (SWAMP)

April 2002

Introduction

This document describes the procedures used by staff of the Surface Waters Ambient Monitoring Program (SWAMP) of the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) for continuous monitoring of general water quality parameters. SWAMP uses YSI 6600 multiparameter probes to monitor four general water quality parameters: pH, electrical conductivity (EC), temperature (T), and dissolved oxygen (DO). This information enables development of a picture of both internally and externally influenced changes to the stream system. Having data that represents both AM and PM conditions, it is possible to discern peaks and drops in parameters that are naturally induced by changes such as sunlight, photosynthesis, and water level, from those due to input of contaminants from external sources. This elegance of analytical breadth was nearly impossible with the traditional and outdated techniques of spot sampling.

SWAMP utilizes continuous monitoring in a large percentage of its sites. At these sites, YSI 6600 sondes are deployed for 12 to 14 day intervals, and monitor pH, EC, T, and DO continuously every 15 minutes. To provide both intra- and inter-watershed data, three sondes are deployed in each of two watersheds. This is favored during years when many sites are being monitored to ensure that all sites have data representing the three hydrologic seasons. In years where fewer watershed sites are being monitored, all six sondes can be deployed in one watershed during a 2-week interval in order to provide a more detailed picture of intra-watershed dynamics.

Continuous monitoring procedure occurs in 12-day cycles throughout the year. The cycle begins when the sondes are deployed in a water body, usually on a Thursday. The sondes take continuous water quality measurements at 15-minute intervals for 12 days, and they are retrieved, in this example on a Tuesday. Maintenance and calibration is performed in the laboratory the following day, Wednesday, which usually requires one person between two and four hours to complete. The two-week cycle begins anew the following day with deployment of the sondes at new sampling sites. The total time devoted to deployment, retrieval, and maintenance of continuous monitoring equipment is 2 ½ days every two weeks, or approximately 40 hours per month. Because deployments and retrievals usually require two staff persons, our continuous monitoring program requires 72 staff person hours per month.

Quality assurance of the probes is regularly monitored by post calibrations in the lab, following sonde retrievals. These involve checking of the probes to determine the margin of deviance from the initially calibrated values, and then recalibration before each deployment. If the post-retrieval numbers are beyond the acceptable range of deviation, the data for that parameter in that sonde's previous site is thrown out. A detailed description of post calibration procedures can be found in the section *Calibration Procedures*. To date, the continuous monitoring probes have shown reliable and nearly trouble-free performance (with exceptions due to environmental factors such as sediment accumulation, decrease in water level, and damage of the DO membrane). While SWAMP is still in stages of development, the continuous monitoring data from the first 6 monitored watersheds is fairly extensive and can be accessed in the Continuous Monitoring folder of the SWAMP database.

Establishing Sampling Locations

Choosing sites for continuous monitoring involves an in-depth reconnaissance of the area of interest, in addition to consideration of the many factors influencing the stream system. A good site for continuous monitoring requires at least a tree, or a stable bank with which to secure the sonde by a chain. Ideally, the site is away from any well traveled foot paths, so as not to attract the attention of locals. It should have sufficient vegetation or ground cover with which to camouflage the equipment. There should be pools at least 1 foot in depth to fully submerge the sonde for the duration of the entire 2-week deployment. Thalwegs are a good spot to look for potential pools, as they generally are the deepest part of a stream. Pools and riffles are an important component of a sampling location, and usually provide good sites for both continuous monitoring and rapid bioassessment studies of the benthic macroinvertebrate communities. An ideal sampling location can be used for a variety of water quality studies, and should include a good substrate variety, natural vegetation, and pools and riffles when present at the site location. This allows for multi-tests in a given site to provide more comprehensive data for comparisons and correlations.

Gaining access to a site is sometimes a cumbersome process, requiring the permission of the landowners or regulating bodies. The streams themselves cannot be privately owned, but the adjacent land is, and permission to cross this land in order to access the sites is necessary before any sampling can be conducted. A permit is often required when the land near the site is on city municipal use property. When a site can be accessed over privately owned residential property, a verbal agreement or signed contract is a reasonable form of permission. Once the permission is granted, the SWAMP can legally access the site so long as the landowners know when sampling will be conducted or have agreed to unlimited access.

Establishing a site for continuous monitoring involves either installing an eyebolt and concrete plug into a stable location on or above the streambank, or locating a large, stable tree that is near (within 20 feet of) the stream, that a chain can be locked around. When a sonde is deployed (explained in the next section), a length of chain attaches the sonde to the eyebolt or tree, preventing the sonde from theft or physical transport. Attaching the sonde and chain to large, secure trees is generally the favored approach, as it requires less time and energy to complete than the concrete plug method. In addition, landowners and land managers are more likely to allow monitoring if it does not involve making permanent alterations to the sampling site. In some locations where riparian vegetation is largely absent, such as areas in eastern Alameda and Contra Coast County, installing a concrete plug may be the only option. In urban locations, bridges or other permanent structures may provide locations for securing chains in place of trees. Locations where continuous monitoring sites have already been established can be found in the excel workbook *Continuous Monitoring* (S drive: Monitoring and Assessment Programs: SWAMP folder: Continuous Monitoring).

Option 1: Securing the chain to a tree or other structure

1. Locate a large, healthy tree, or another permanent stable structure such as a bridge support. The object should be sufficiently large and stable such that there is very little possibility that it will be removed or destroyed, either by natural or human processes.

2. Lock one end of the chain around the base the tree, or another suitable object. Attach the other end of the chain to the sonde and deploy it in the stream as usual. At sites that may receive many visitors, or is visible from highly trafficked areas, camouflage the chain with leaves, sticks and debris. The chain should be secured high enough above the water surface so that increased flows will not make it impossible to safely retrieve the sonde.

Required Equipment:
- Sonde and armoring
- Three corrosion resistant locks
- Heavy chain (at least 20' long)

Option 2: Securing the chain to an eyehook in a concrete plug

1. Choose a stable (non-eroding) location on the streambank that is above bankfull for the installation of a permanent eyehook. At sites that receive a lot of foot traffic it is a good idea to choose a location that is not visible or that is obscured by vegetation.

2. Dig a hole approximately one foot in diameter and one foot deep.

3. Pour one sack of Quickcrete into the hole. The dry Quickcrete should be several inches below the top of the hole.

4. Insert the eyebolt with the bolt attached near the end into the Quickcrete, and stir the quickrete to settle and level.

5. Fill the bucket less than ¼ full from the nearest water source.

6. Slowly pour about one gallon (one fifth of the bucket's volume) onto the dry Quickcrete. We generally use between 1 and 1.5 gallons. If the Quickcrete is not saturated, it may be necessary to add more than 1 gallon.

7. Stir the Quickrete with the eyehook and place the eyehook so that it is 2-3 inches above the top of the Quickcrete, as the Quickcrete may expand in volume with the addition of water.

8. Allow the Quickcrete to set for at least 20 minutes before disturbing anything. When possible, wait the 20 minutes so as to ensure the eyebolt is not removed by anyone before the Quickrete is completely dried.

9. Cover the Quickcrete with 1-2 inches of loose dirt. Hide eyehook/Quickcrete and chain with some organic debris or rocks.

Required Equipment:

- Sonde and armoring
- One ½" diameter, ~8" long eyebolt
- One 50 pound bag of Quickcrete
- One 5 gallon bucket
- One shovel
- One to two gallons of water (from creek)
- Three corrosion resistant locks
- Heavy chain (at least 25')

Sonde Deployment

1. Check to see that the sondes were calibrated the previous day. If more than 24 hours has elapsed since calibration, the DO probe should be recalibrated, following the instructions in the Calibration and Maintenance section.
2. If it was not done previously following calibration, set-up the sonde for continuous monitoring:
    - Connect the 650 data logger to the sonde via the field cable (make sure the connection ports are clean and dry; do not allow water to enter).
    - Turn on the 650. Connect to the sonde from the Sonde Main menu.
    - Select 1-Run from the Main menu.
    - Select 2-Unattended sample.
    - Verify that the interval is 15 minutes, the start date and time are correct (time should be the next 15 interval), and that the duration is set to 365 days (it will not actually be deployed this long, but that doesn't matter).
    - Select 5-file and enter the file name. The file name consists of the six-digit site name, e.g. SPA070 (once we upload the file back at the office we will change the name to include both the site and the deployment date, but it is not necessary to do that here). It is not necessary to enter anything for 6-Site.
    - Verify that the battery life is sufficient for the duration of the study. Should have at least 40 days for a 2-week interval since sondes frequently use battery life more quickly than stated.
    - Select Start Logging. A screen will appear asking if you are sure. Select 1-Yes. The original set-up screen appears again. Here, you can continue pressing escape until the logger disconnects at which point you can turn the power off. Make sure to screw the top onto the sonde tightly before deployment so as to prevent seepage of water.

3. If it was not already done, fill up the calibration cup with ¼ inch of water. Screw the calibration cup onto the sonde halfway, so that it is still open to the atmosphere.

4. Load the field vehicle with the sondes, armoring, and all necessary equipment, keeping the sondes upright if possible to avoid leakage of the water in the calibration cup (see Deployment Equipment Checklist).

5. Locate or establish the site (see *Establishing Sites* section).

6. Unscrew the loosened calibration cup from the sonde. Screw on the probe guard, being careful to leave it a little loose, as it can be very hard to unscrew. Make sure to avoid touching any part of the DO membrane surface.

7. Check to be sure that the sonde is ready to be deployed: that it is currently engaged in unattended monitoring, that the battery compartment is securely attached, and that the probe guard is on. Place the sonde, probe guard down, into the armoring. For consistency, make sure the sonde is placed into armoring with the same number as the sonde. Place the armoring cap on the armoring, and insert and lock the pin. For the lock combination, see Matt, Daniella, or Steve.

8. Attach and lock one end of the chain either to a tree, the eyebolt, or another stable structure.

9. Attach and lock the other end of the chain to the top of the armoring.

10. Choose a suitable location in the stream to place the armoring. The most important consideration is that the sonde should be placed in a location that minimizes the amount of fine sediment entering the armoring. Try to avoid placing the sonde at the bottom of pools or other areas where fine sediment is accumulating on the bed. Good locations are generally above riffles or in runs. Additionally, it is important to insure that the sonde remains below the water surface for the entire sampling interval (6 inches from the top of the sonde to the water surface is generally a safe minimum). If you are deploying during or after a rainfall event, however, keep in mind that base flow may be significantly less than storm flow. The final consideration is the anthropogenic disturbance potential: choose a location that is hidden or not likely to be disturbed by curious or angry passers-by.

11. If the site has a high anthropogenic disturbance potential, camouflage the chain with brush, grass, woody debris, stones, or soil as thoroughly as possible.

12. Fill out the continuous monitoring field deployment sheet. At a minimum, note the date and time of deployment and the exact location of the sonde (include a map).

Sonde Retrieval

1. On the day of retrieval, bring the calibration cups and at least 1 liquid cup of distilled water.

2. At the site, remove the sonde from the stream, unlock the locks and remove the chain from the armory. If the locks do not open immediately, pound them upside-down against a rock or the ground in order to loosen up any trapped sediment. Continuous rinsing in the creek may be necessary. Make sure to push and pull forcefully, and note that it may take up to 5 minutes to loosen the sediment adequately enough to open the lock.

3. Remove the sonde from the armory and clean the armory, chain, and sonde in the river to remove any sediment, rocks, or trapped fish (yes this does happen). Make sure to bring a sponge and gloves to the site for on-site cleaning.

4. Carry the equipment back to vehicle and immediately replace the sonde guard with a calibration cup filled ¼ inch full of distilled water. Do not stop logging, and place the sonde in an upright position so as to prevent leakage of water during transport.

5. When back at laboratory or office, do not stop logging until there have been at least 4 hours of continuous logging following removal of the sondes from the creeks. This is to ensure sufficient data collection to represent the deviation of probes from their initial calibrated values. If the DO membrane is not kept moist, the post retrieval calibration information may be significantly modified.

Calibration and Maintenance

Once the sonde is retrieved, careful procedures need to be followed to insure data quality assurance and proper sonde maintenance. Immediately after being removed from the water, the sonde should be loosely placed into a calibration cup filled with ¼ inch of water, as described above. Once back in the lab, the sondes should be left for at least one hour, in order to acquire DO readings in saturated air at a relatively stable temperature. Usually, sonde retrieval takes a full day in the field, and the sondes are left over night in the lab before maintenance and calibration is performed the next day. The maintenance and calibration procedures are performed at the sink in the GIS Lab on the 15th floor.

DO Probe Check

1. End the unattended sampling: Connect the 650 data logger to each of the sondes, go to Sonde Menu: Run: Unattended Sample, scroll to the bottom, click on Stop Sampling, and confirm (yes) that you want to stop sampling.

2. Before disconnecting, upload the data file onto the 650. Go to File: Upload and select the appropriate file. Select PC6000 format.

3. Connect the 650 to the computer equipped with a connection cable (currently on Matt's computer). Open the Ecowatch software, open the Comm menu, and select Sonde. At the same time, turn on the 650, go to File: Upload to PC, and select the appropriate file. This process uploads the data file and places the .dat file in a folder entitled Ecowatch Data.

4. With the Ecowatch software open, go to File: Open and select the appropriate file. Ecowatch presents a graph of the parameters versus time. Perform a cursory examination of the data fro any obvious anomalies (e.g. very sudden jumps). Carefully examine the DO % Saturation data for the period the sonde was left in the laboratory, when the probe was in water-saturated air in the calibration cup. These values represent the post-deployment calibration check for DO, and should be entered on the Calibration form.

5. If there are anomalies in the DO data, perform the following procedure to check the function of the DO probe. Fill a calibration cup with fresh water. With the probe in air, activate the Discrete Sample function and allow the readings to stabilize. Next, place the sonde into the calibration cup filled with water, making sure there is enough water to cover the calibration sensor. Continuing with the Discrete Sample, observe any changes in the DO. If the readings rise slightly and become jumpy when the sonde is placed in water, there is likely a puncture in the DO membrane. The jumpy values are a result of "crosstalk" between the DO and conductivity sensors because of the conductive water. If the readings appear normal (near 100% saturation), the anomalous data must be due to another cause.

6. From the Advanced Menu, select CalConstants and observe the DO Charge. If it is greater than 75, the DO probe needs to be resurfaced before adding a new DO membrane.

7. Remove the O-ring on the conductivity probe, and carefully remove the old DO membrane. Inspect the DO probe surface. If the silver electrodes show significant darkening, resurface the probe face with the fine sandpaper disk found in the 6035 reconditioning kit. After sanding, rinse the probe face repeatedly with purified water.

Cleaning

1. Thoroughly clean the sondes with tap water and a sponge. Be very gentle when touching the probes themselves- never scrub delicate parts of the probes such as the tip of the DO probe. Make sure to remove any debris caught between the probes. The base of the sonde where the probes are connected can be cleaned with the sponge or a toothbrush. Wipe off any sediment or silt around the probes with a paper towel.

2. Clean the conductivity sensor with the brush provided in the maintenance kit.

Calibration

Calibration is of utmost importance for the quality assurance component of the SWAMP. With proper pre- and post-retrieval calibrations, it becomes possible to ascertain the deviation of parameter measurements throughout the duration of the deployment. There are manufacturer percent deviations, which is the percent of measured instrument drift that can occur under even "perfect" conditions. YSI 6600 sondes generally have a 2 % error for a given range of data values. Beyond these ranges, YSI does not guarantee the same accuracy. These YSI parameter specific ranges of accuracy, along with the associated percent instrument drift, are listed in the table below.

Parameter	Units	Range of Data Accuracy	% Instrument Drift
Dissolved Oxygen	% Saturation	0-200	2%
Dissolved Oxygen	% Saturation	200-500	6%
Electrical Conductivity	mS/cm	0-100	2%
pH	pH units	0-14	2%
Temperature	Degrees C	-5 to +45	2%

For the purposes of the SWAMP goals, 2% deviation following a 2-week deployment may be unattainable due to external environmental influences. For this reason, the acceptable percent instrument drift used by the Texas Natural Resource Conservation Commission (TNRCC) have been temporarily adopted. The levels of acceptable instrument drift used by TNRCC are slightly more lenient, thus accounting for inevitable environmental interferences. These acceptable instrument drift values are shown in the following TNRCC mulitiprobe calibration page. This was taken from the Texas Natural Resource Conservation Commission's *Surface Water Quality Monitoring Procedures Manual (1999).*

YSI 6600XL Calibration Record

Pre-run Calibration

Date [ ] Time. [ ] Altitude (ft) [ ] Barometric Press (mm Hg). [ ]

S/N [ ] Battery Voltage (%) [ ] Initials [ ]

Function	Temp of Standard	Value of Standard	Initial Reading	Calibrated to	Comments
Dissolved Oxygen (mg/L)			mg/L	mg/L	O_2 Saturation Value(%)
S. C. (high)					
S C (low)					
pH Buffer 4 00					
pH Buffer 7.00					
pH Buffer 10 00					

Calibration Information

Record the following diagnostic numbers after calibration			Comments
Conductivity Cell Constant		Range 4.5 to 5 5	(Sonde Menu - Advanced - Cal Constants)
DO Charge		Range 25 to 75	(Sonde Menu - immediately after DO calibration)
DO Gain		Range 0.7 to 1 7	(Sonde Menu - Advanced - Cal Constants)
pH MV Buffer 4 00		Range 180 +-40 MV	(Sonde Menu - immediately after pH 4calibration)
pH MV Buffer 7 00		Range 0 +- 40 MV	(Sonde Menu - immediately after pH 7 calibration)
pH MV Buffer 10 00		Range -180 +- 40 MV	(Sonde Menu - immediately after pH 10 calibration)
pH Slope		Range 165 to 180 MV	(pH 7 MV - pH 10 MV)

Post-run Calibration Check

Date [ ] Time [ ] Altitude (ft) [ ] Barometric Press (mm Hg) [ ]

Function	Temp. of Standard	Value of Standard	Instrument Reading	Calibration Value	Drift	Post Calibration Error Limits
Dissolved Oxygen (mg/L)			mg/L	mg/L		+-0.5 mg/L
S C (high)						+- 5%
S C. (low)						+- 5%
pH Buffer 4.00						+- 0 5 standard units
pH Buffer 7.00						+- 0 5 standard units
pH Buffer 10 00						+- 0 5 standard units

Notes ____________________

Rev 3/8/02

According to these acceptable levels of instrument drift, we can use our post-deployment calibration information to determine whether or not the data is reliable. If the deviation from the pre-deployment is greater than those stated in the TNRCC calibration record form, the entire data set for that deployment may be thrown out. It is first necessary, however, to look closely at the data uploaded from the sonde to ensure that the significant deviation from the calibrated value did not just occur during transport of the sonde from the site to the lab. The step-by-step calibration procedure guidelines for both pre- and post-deployments are described below.

- Electrical conductivity calibration: Before beginning calibration of the conductivity probe, rinse the probes with distilled water and pat dry with paper towels or Chem Wipes. Liquid easily contaminates the conductivity standard. Pour YSI 3161 Conductivity Calibrator (1.0 mS) into a clean, dry calibration cup up to about ¾ its volume (enough to cover the conductivity sensor). Place the sonde into the calibration cup. Press "Sonde Menu" and select "File". Check the conductivity by pressing "Calibrate" and then selecting the "Conductivity" option. Only press "enter" one time, and record the conductivity value shown. This first number tells you how far off the deviation is from the standard, and if it is an unacceptable deviation, the data from the previous monitoring for electrical conductivity should be thrown out and cause of faulty reading should be ascertained. If within an acceptable margin, continue by pressing "Enter" to confirm calibration. It should now calibrate to1.0 mS/cm for the next deployment. Record the new number shown as the calibrated value.

- pH calibration (ph 7.00): Pour YSI 3822 pH 7.00 solution over probes and then into the rinsed calibration cup to about ¾ of volume. Screw in the sonde and connect to the data logger. After connection, press "Sonde Menu", "File", "Calibrate" and select "pH". Choose a 2-tier calibration and enter the first pH as 7.00. Press enter one time to check the pH. Record this number and if within a reasonable margin of deviation (<0.5 from calibrated pH), continue calibration by pressing "Enter". Record new calibrated pH and press continue.

- Calibration cont. (pH 4.00): Rinse probes with distilled water and YSI 3821 pH 4.00 solution. Fill up calibration container with pH 4.00 to ¾ volume and screw in the sonde. Enter the second pH value of 4.00 and press enter once. Record this value and if within the 0.5 deviation range, continue calibration by pressing "Enter". Once the two pH values are calibrated, rinse probes again with distilled water and pat dry.

- DO Check: Check DO probes by pouring about ¼ of an inch of distilled water into the calibration container. Screw in the sonde loosely and connect to the data logger. Once connected, press "Sonde Menu", "Run", and "Discrete Sample". Waite at least 10 minutes before reading the DO value. This allows proper time for the air to become water saturated. After 10 minutes, record the DO value If value is close to 100% (within 5%), DO membrane may be reused, but due to the fragility of the membranes, it is recommended to change the DO membranes before each deployment.

- Changing the DO membrane: Remove the existing membrane and rubber ring. Place 2 drops of KCl provided in the YSI dissolved oxygen kit #5775. If there are bubbles or material in the solution, gently blow it off and reapply. Careful not to touch the part of the membrane going over the probe surface, hold one side of the new membrane and stretch the other side over the tip of the probe so that there are no bubbles or wrinkles at the surface. Reuse the rubber ring and cut off the extra membrane around the ring using a razor blade.

- DO Calibration: Once the membrane is changed, it needs to be burned in overnight before calibration and deployment. Go into "Sonde Menu" and press "Run" and "Unattended Sample". Confirm this with "Begin Logging" and "Yes". Leave the sonde in an upright position with the calibration container and ¼ inch of distilled water slightly screwed on to allow passage of oxygen into the container. Exit by pressing Esc a few times and leave the sonde to burn in overnight.

- DO Cont. (next day): The following morning, connect the 650 logger to the sonde, press "Sonde Menu", "Run", "unattended sample", "Stop Logging" and "Yes". Press "Esc" to return to main menu. Select "Calibrate", "Dissolved Oxygen" and "Enter". The barometric pressure is measured internally and does not need to be changed. You want to calibrate to percent saturation, not mg/L. The standard for this is 100%. After pressing enter to calibrate, it will take about 40 seconds for the probe to stabilize. Then, press "Enter" to continue, "Esc" to return to menu and press "Run" and "Discrete Sample". This is to check the DO membrane following calibration and burn-in time. The reading should stabilize at around 100% after about 30 seconds of decreasing values. These values should be recorded at the bottom of the calibration sheet. If the values seem jumpy, the DO membrane may have a hole in it, and an advanced look by submerging the probe in distilled water after 5 minutes in the open air. If the discrete sample when submerged under water shows very jumpy values, the DO membrane must be replaced and the process of burning in must be repeated.

- Last check: As a back up check to ensure that levels are all within an acceptable range of deviation, go to the menu and select "Advanced", and "Cal Constants". These numbers should all be within the acceptable range delineated in the YSI manual. The sonde is now ready for deployment.

Data Analysis-

The data collected by the continuous monitoring sondes is uploaded into an interim SWAMP database in order to enable in-house analysis of preliminary data results. This database is being used until the permanent statewide database (SWIM II) is implemented. The workbook *AllStatsData.xls* (S-drive:Monitoring & Assessment:SWAMP:Continuous Monitoring) incorporates the raw data uploaded from the sondes into EcoWatch, calculating basic statistical information (mean, median, min, max, 25%, and 75%) for DO, Temperature, Electrical Conductivity, and pH results. These values are supplemented with individual site descriptions, and will ultimately be plotted against the bioassessment, water quality, and physical measurement data for each site to determine significant correlations. The presentation of data will be in the form of linear regression plots, scatter plots, and GIS layers. Once the data is appropriately analyzed and placed into maps and graphic representations, the results will be made available to the public in a final watershed report on the Regional Water Quality Control Board website.

Field Day Checklist

- Armoring
- Sondes (numbers on armor and sondes should be matching)
- First Aid Kit
- Hex Key
- Data logger/Cables
- Chains/Locks
- Eyebolts
- Quickrete
- Shovel/Bucket
- Waders
- Maps/Site list
- Gloves
- Sponge
- Paper towels
- Plastic garbage bags or tarp
- YSI Instruction manual
- Digital camera
- GPS
- Back-up batteries (8 C-cell)
- Field notebook and pencil
- Flagging for site ID
- Distilled water
- If doing post-calibration in field:

  *Standards
  *YSI DO kit (KCl, rubber rings, razor, membranes)
  *Calibration containers
  *Funnel
  *Distilled water
  *K-dry towels