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RMP Regional Monitoring News

Non-Point Source Pollution: a Primer

Watersheds as Contaminant Sources

by Jennifer Hunt (jhunt@sfei.org) and Lester McKee (lester@sfei.org)

Since the passage of the federal Clean Water Act in 1972, regulatory agencies have identified and controlled many of the sources of chemical contaminants that enter San Francisco Bay (the Bay). However there is a major source of contaminants that is more difficult to measure and control. This type of source is referred to as non-point source (NPS) pollution. As the term implies, this source can not be traced back to a single location like a wastewater outflow pipe. Non-point source contaminants are distributed throughout the watershed and are mostly mobilized into aquatic systems through storm water flows. Potential NPS contaminants include fertilizers and pesticides used on residential and agricultural land, nutrients from livestock areas, and chemicals from urban and suburban runoff (EPA, 2003). These contaminants enter the Bay through storm water drainage systems, creeks, and rivers. In order to implement actions to reduce storm water contaminant loading we need to identify the sources in the urban/suburban landscape and quantify the amount of contaminants that NPSs are contributing to the Bay.

> Non-point source pollution can not be traced back to a single location like a wastewater outflow pipe.

Storm Water Runoff – Evolving Estimates of Contaminant Inputs into the Bay

The San Francisco Regional Water Quality Control Board (Regional Board) has developed Total Maximum Daily Load (TMDL) reports which quantify the storm water contaminant contributions for two of the highest priority pollutants

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Also Inside This Issue

Emerging Contaminants

Endocrine Disrupting Chemicals (EDCs)

by Daniel R. Oros (daniel@sfei.org) and Jennifer Hunt (jhunt@sfei.org)

Several classes of environmental synthetic contaminants are potentially threatening aquatic life in the San Francisco Bay and elsewhere. These contaminants include both persistent and non-persistent chemicals that may adversely affect natural endocrine system functions (IPCS, 2002). The endocrine system is responsible for maintaining natural bodily functions such as metabolism, growth, reproduction, and development. Increasing evidence suggests that some synthetic chemicals can interfere with endocrine system functions in humans and wildlife. Chemical classes of concern include industrial waste products such as dioxins (TCDD) and furans, industrial chemicals such as PCBs and organometals (such as tributyltin which was used as an anti-fouling agent in boat paint), organochlorine pesticides and their degradation products, plastics-related chemicals such as phthalates, flame retardants such as polybrominated diphenylethers (PBDEs), and non-ionic surfactants such as alkylphenol ethoxylates and their degradation products such as 4-nonylphenol (U.S. EPA, 1998), all of which are present in the Bay (RMP, 2002). Two emerging contaminants of particular concern are 4-nonylphenol and a class of chemicals known as phthalates. Other endocrine disruptor compounds such as PCBs and organochlorine pesticides are routinely monitored by the RMP. In all cases it remains difficult to demonstrate any observable health effects and exposure to any single endocrine disrupting chemical (EDC).

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Regional Monitoring Program for Trace Substances
A Cooperative Program Managed and Administered by the San Francisco Estuary Institute

Measuring the Effects of Sediment Contamination on Benthic Communities: A New Method

by Aroon Melwani (aroon@sfei.org), Bruce Thompson (bruce@sfei.org), Sarah Lowe (sarahl@sfei.org)

One of the Regional Monitoring Program's (RMP) main objectives is to measure the effects of contaminants on aquatic life in San Francisco Bay. Wildlife are exposed to many contaminants, including PCBs, pesticides, and mercury, through a variety of different pathways. Benthic (or sediment-dwelling) organisms such as clams, worms and crustaceans are an important part of the Bay ecosystem, constituting a primary food source for fish and birds and influencing sediment stability and geochemistry. RMP scientists have developed a multi-metric approach for assessing the effects of contaminants on benthic communities in response to a need of the San Francisco Bay Regional Water Quality Control Board.

Assessment of contaminant effects on benthic communities provides important information on a major ecosystem component as well as improved understanding of the potential impacts to the Bay food web. If contaminants are affecting these organisms then this may have a reverberating effect on other organisms higher up in the food web. Benthic animals are also considered useful environmental indicators as they exhibit limited mobility and are deposit feeders. Limited mobility implies that impacts are more likely the result of contaminants found in the local environment. Many benthic animals ingest sediment and consequently digest the particulate organic material that is bound to the sediment. Contaminants are often associated with organic material and are also ingested during feeding, increasing contaminant exposure and the likelihood of effects.

Defining the New Assessment Method

We performed a benthic assessment using data from the RMP Benthic Pilot Study (Thompson *et al.* 2000), RMP, Bay Area Clean Water Association's Local Effects Monitoring Program, Department of Water Resources, and the Bay Protection and Toxic Clean-up Program (**Figure 1**). In order to assess any potential effects of contaminants on benthic communities, evaluation tools had to be developed. For this study, benthic communities were assessed by 1) total number of taxa in a sample, 2) total abundance of organisms/sample, 3) total number of two specific contaminant tolerant benthic worms and 4) proportion of sensitive benthic amphipods and 5) total number of sensitive molluscs. Benthic organisms can develop tolerance or sensitivity to increasing concentrations of contaminants and organic material in sediments. Moderate contaminant concentrations may cause the species composition at a site to shift as sensitive species are replaced by tolerant ones. Elevated organic material concentrations that usually occur with increasing contamination can provide additional nutrition that favors the growth of tolerant species, as long as their toxic thresholds are not exceeded. However, as a site becomes

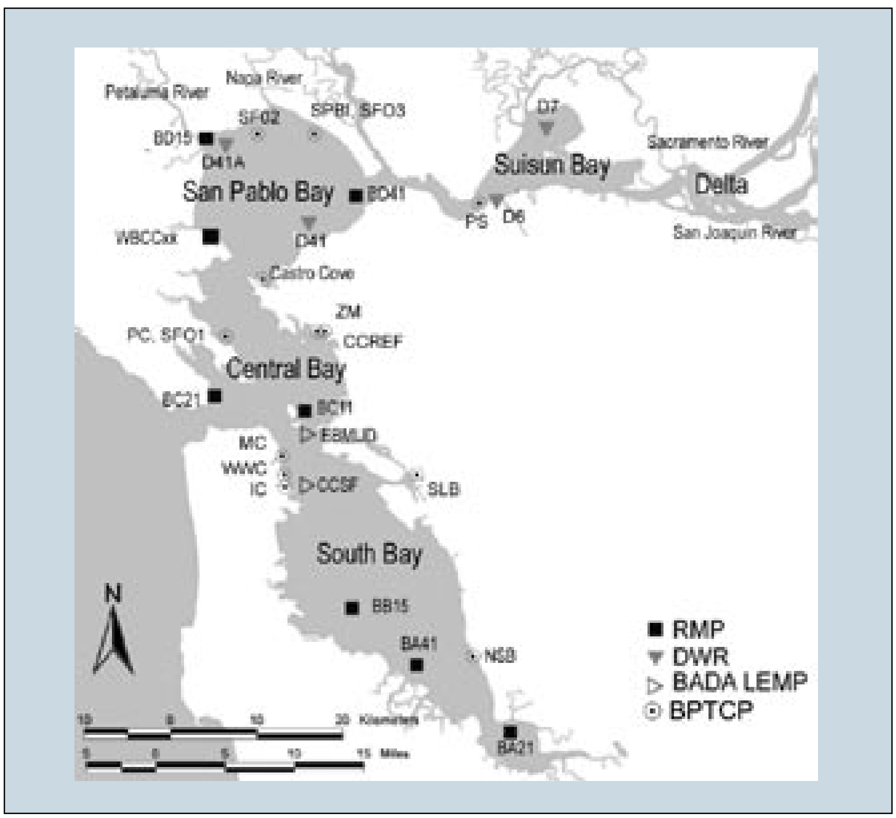

Figure 1: Map of San Francisco Bay sampling sites used in the benthic assessment.

further contaminated or develops extremely high organic enrichment (*e.g.* low dissolved oxygen and high sulfide), abundance and species diversity may rapidly decline due to sediment toxicity.

Benthic samples were identified using the salinity regime and benthic community structure. "Central Bay" samples were designated high salinity samples while Suisun Bay, San Pablo Bay, and parts of the South Bay were designated "estuarine" due to moderate salinity regimes. Since "clean" reference sites could not be identified within the Bay, background reference ranges (minimum and maximum for each assessment metric) were established from the literature. These reference ranges were used for comparison to all samples included in the assessment procedure.

"Central Bay" community	No. taxa	Total abundance	Amphipod taxa sensitive species	Capitella capitata (benthic worm) tolerant species	Assessment Value
Reference Min	21	97	2	0	
Reference Max	66	2,931	11	13	
Site BB15	24	**81**	**0**	1	2
Site CCSF-04	**13**	**27**	**1**	0	3

Table 1: Assessment calculations from two Central Bay community samples, based on the reference minimum and maximum for each metric. Numbers in bold type indicate sample metric outside reference range and that sample gets a score of 1 for that metric

Calculating Assessment Values

Assessment values (AVs) were calculated for each sample included in the analyses, using the indicator metrics described above. The AV of a sample represents the sum of the number of metrics that were outside the minimum-maximum reference range. Samples with an AV of 0-1 were considered unimpacted, samples with an AV of 2 were considered to be slightly impacted, samples with an AV of 3 were considered to be moderately impacted, and samples with an AV of 4-5 were considered severely impacted. An example of the reference minimum/maximum range and an assessment of two Central Bay sites is given in **Table 1.** Site BB15 had an AV value of 2 indicating a slight impact. At this site the total abundance and proportion of sensitive amphipods were less than the reference minimum giving this site an AV of 2. Thirty-three percent of the high salinity sites had an AV value of 3. All other high salinity sites were slightly impacted (AV=2). Forty-seven percent of the moderate salinity sites were severely impacted (AV=4-5) while the remaining sites showed slight to moderate impact.

The assessment procedure showed that many of the impacted samples had one or more assessment indicators above the reference range. Samples designated by moderate impact (AV=3) indicated elevated numbers of taxa and abundances. However, the severely impacted sites (AV=4-5) (*e.g.* in San Leandro Bay) exceeded reference ranges in most or all of the five assessment indicators. The most severe benthic impacts were associated with sites located in sub-embayments, coves, and channels along the margins of the Bay. The Bay margins receive direct inputs from numerous tributaries and storm drains that deliver sediment, organic material, and contaminants (Leatherbarrow *et al.* 2002). The deeper, offshore sites were associated with a much lower incidence of benthic impacts. Benthic impacts were observed in 14.3% of sites located near wastewater discharges.

If contaminants are affecting benthic organisms, then this may have a reverberating effect on other organisms higher up in the food web.

A Useful Tool

The assessments showed that the level of impact (AVs) on benthic communities was significantly correlated with levels of sediment contamination, and accurately reflected sediment toxicity results. However, impacts could not be solely attributed to sediment contamination due to the close association between sediment contamination and organic material in estuarine systems. This assessment procedure illuminated benthic impacts that were not apparent from toxicity tests alone. The assessment provides an additional component to evaluate sediment impact, and should be used along with sediment contamination and toxicity information (*i.e.,* the sediment quality triad as suggested by Chapman *et al.* (1997) in a weight-of-evidence approach to evaluate sediment conditions in San Francisco Bay. This benthic assessment method has been compared to another method developed for Southern California in a recent report to the State Board (Ranasinghe *et al.* 2004), and will be used in development of Sediment Quality Objectives for California Bays and Estuaries later this year.

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News! News! Read All About It! First Issue of The San Francisco Bay Mercury News Goes to Press

by Meg Sedlak (meg@sfei.org)

Under the auspices of the Regional Monitoring Program, SFEI is now distributing a newsletter that is a compilation of mercury research activities currently underway in the San Francisco Bay Area. The goal of the newsletter is to keep researchers, regulators, and the regulated community informed of mercury research activities in the Bay in order to foster collaboration and to facilitate discussion on emerging issues.

For our first issue in September 2004, researchers provided a short summary of their current research and recently accomplished milestones. Summaries from that issue included:

- **Evaluation of Mercury Transformation and Trophic Transfer in the San Francisco Bay/Delta**. Researchers from the USGS, University of Maryland and State University of New York have embarked on a three-year CALFED project to investigate processes controlling mercury transformations and bioaccumulation in the San Francisco Bay-Delta. Part of the impetus for this work was the observation that mercury contamination of biota is low in the Central Delta and high in the rivers flowing into the Delta.
- **Pilot Program for Monitoring, Stakeholder Involvement, and Risk Communication Relating to Mercury in Fish**. This project will be a collaboration between the California Department of Health Services, California Office of Environmental Health Hazard Assessment, Moss Landing Marine Laboratories, SFEI and the University of California at Davis. The goal of this Program is to monitor mercury in fish, develop methods for incorporating stakeholder participation in the design of monitoring plans, and effectively communicate the human health risks from the consumption of contaminated fish. This project is a multi-investigator effort that will commence in 2005.
- **Concentration and Production of Methylmercury in Bay Wetlands**. The US Army Corps of Engineers (USACE) is evaluating the suitability of dredge material for fill. The focus of this research is on factors that increase methylmercury production. USACE is primarily studying the Hamilton Army Airfield, China Camp, and the Sonoma Baylands.
- **Mercury and Methylmercury Processes in North San Francisco Bay Tidal Wetland Ecosystems**. SFEI is leading a multi-team research project examining processes that lead to mercury exposure and accumulation by several threatened or endangered wetland bird species, located in five tidal marshes on the Petaluma River.

In addition, several local academic institutions are actively pursuing mercury research. Dr. Russ Flegal, a nationally-recognized expert in the area of trace metals, provided several summaries regarding on-going research activities at the University of California Santa Cruz. Recently published research from UC Santa Cruz included: a study of the mercury concentrations in petroleum products and their contribution to atmospheric mercury fluxes in the Bay area (Conaway et al, in press); geochronology of mercury fluxes in the South Bay (Conaway et al., 2004); and mercury speciation in Bay waters (Conaway et al., 2003). Two University of California Berkeley students recently received their doctorates for mercury research. Dr. Anna Mehrotra's research demonstrated that the addition of iron to sediments reduces the rate of methylmercury production by up to 95 percent. The results of her research are published in *Environmental Science and Technology* (Mehrotra et al., 2003). Dr. Helen Hsu observed that wastewater effluent contains relatively high concentrations of a ligand that is capable of forming extremely strong complexes with mercury (Hsu and Sedlak, 2003). Drs. Hsu and Mehrotra's research was overseen by Professor David Sedlak.

The first issue of the newsletter can be downloaded from the SFEI web site at http://www.sfei.org/rmp/mercury_newsletter/mercury_newsletter10_06_04.htm.

SFEI welcomes contributions to the newsletter and is actively seeking new contributors for our next issue that will be distributed in February 2005. If you have a summary for the newsletter or questions or comments, please e-mail or call Meg Sedlak at SFEI (meg@sfei.org or tel. (510) 746-7345).

Also of note, SFEI will also be hosting the San Francisco Bay Wetland Mercury Research Coordination Meeting on February 23, 2005. This workshop brings together researchers, regulators, and stakeholders to discuss recent developments in the area of wetland mercury research. If you are interested in receiving information about this workshop, please e-mail Meg Sedlak at meg@sfei.org.

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What We're up to: Overview of the RMP in 2005

by Meg Sedlak (meg@sfei.org) and Jay Davis (jay@sfei.org)

In 2005, the Regional Monitoring Program for Trace Substances (RMP) enters its thirteenth year of monitoring and research. Each year, SFEI has adapted the RMP in response to changes in the regulatory landscape, advances in our understanding of the Bay, and a continual drive to adjust the Program to better meet its objectives. Part of this adaptation process includes a periodic review of the RMP objectives that are the foundation for all of the Program's activities. In 2004, a review of the management objectives adopted in 1998 was undertaken to evaluate whether they adequately addressed current management questions and the current state of knowledge about the Bay. Based on this review and comments solicited from scientists, regulators, and interested stakeholders, the following revised objectives were developed:

1) Describe the distribution and trends of contaminant concentrations in the Estuary;
2) Project future contaminant status and trends using best understanding of ecosystem processes and human activities;
3) Describe sources, pathways, and loading of pollutants entering the Estuary;
4) Measure pollution exposure and effects on selected parts of the Estuary ecosystem (including humans);
5) Compare monitoring information to relevant standards; and
6) Effectively communicate information from a range of sources to present a more complete picture of the sources, distribution, fate, and effects of contaminants in the Estuary ecosystem.

photo by Don Weden

In response to these changes, the 2005 RMP has been specifically designed to address these objectives. Further details on the 2005 Program are presented in the 2005 RMP Program Plan and the 2005 RMP Detailed Workplan (available on the RMP homepage of the SFEI website).

One highlight of the 2005 Program will be the beginning of a multi-year, joint CEP and RMP effort to further develop the multi-box PCB model and gather information needed to refine model predictions. The multi-box model will be improved through additional testing and review, addition of quantitative uncertainty analyses, and enhanced graphical output. Other parts of the joint multi-year scope address further documentation of the multi-box model by USGS, a two-phase field study of sediment dynamics, and application of the model to three other pollutants. Work on one of the additional pollutants will begin in 2005.

Models forecasting contaminant trends in the Bay are sensitive to the magnitude of loads from tributaries. Three special studies in 2005 will enhance our understanding of the inputs to the Bay from tributaries. The Mallard Island study is a study of contaminant loads from the Sacramento and San Joaquin Rivers. The purpose of the Mallard Island study is to develop a better understanding of the relative importance of inputs from the Central Valley Rivers. Similarly, the purpose of the Guadalupe River study is to develop a better understanding of loads from small tributaries due to transport during storm events. Present estimates of sediment loads from small tributaries are known to be highly variable and inaccurate, and to have a large influence on recovery of the

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2004 CalFed Science Conference: Summary of the Methylmercury Sessions

by Josh Collins (josh@sfei.org)

The 3rd Biennial CALFED Bay-Delta Conference convened in October of last year. There were two sessions synthesizing the science & management of mercury in the Bay-Delta. This article is a summary of those sessions.

Mercury (Hg) can become an environmental problem when sulfate-reducing anaerobic bacteria, in the presence of organic substrates, form methylmercury (MeHg), a highly toxic compound that endangers wildlife and people by accumulating in their food.

The spatial and temporal variation in MeHg production is mainly a function of the availability of inorganic mercury to methylating bacteria. Typically only a small percentage (e.g. $<5\%$) of total inorganic mercury is available for methylation. The amount of MeHg that actually becomes available for bioaccumulation depends on many environmental factors operating at different spatial scales, from watersheds to microbes. Scientists are working to prioritize these factors for management actions.

Methylmercury production and ultimate bioaccumulation might be managed through source reduction and land use practices, including strategic habitat restoration designs. The strategy for solving the problem calls for integrated mercury investigations to build a scientific foundation for restoration, environmental management, assessment, and eventual reduction of mercury-related risks in the Bay-Delta ecosystem.

Scientists and managers need to work together to determine the importance of methylmercury production relative to other potential problems in river and wetland restoration. Scientists are striving to explain the different effects of alternative designs and management practices so managers can optimize the benefits of restoration projects.

Most of the mercury sources in the ecosystem are well documented. Mercury ore (native mercury, cinnabar, and metacinnabar), was mined in the Coast Ranges of California and used at placer and hardrock gold mines in the Sierra Nevada and Southern Klamath Mountains. The legacy deposit of mercury from gold mining operations is concentrated in the Central Sierra, whereas the mercury mines are much less numerous but distributed more uniformly throughout the Central Coast Ranges. Newer sources, such as atmospheric deposition, urban run-off, and effluent from wastewater treatment plants also contribute to the mercury problem in the Bay-Delta ecosystem. The importance of the legacy and newer mercury sources is discussed in this issue (See cover story).

Methods have been developed to identify and manage mercury-laden soils and sediments within mining sites. The identification and management of such sediments are based on knowledge about mining operations and mercury behavior that can be transferred from one site to another to improve remediation and restoration efforts.

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In general, mercury is associated with very fine sediments deposited from historical gold and mercury mines. Settling ponds and fine-grained lenses of material that may cover older tailings contain significant quantities of fine-grained material. Course sediments that have been piled as tailings generally contain a smaller proportion of fine-grained material. The distribution of mercury from mining sources in the major watersheds is not known well enough to estimate potential yields, except in a few watersheds. Some upstream sources of mercury have been identified that can be quarantined or cleaned. Estimates of the effects of local remediation on the overall mercury load need further evaluation.

Mercury that has moved from mining sites into aquatic systems can be methylated in the water column or in the oxic-anoxic boundary layers of sediments. Downstream transport and redistribution of mercury from contaminated sources may cause a higher degree of reactivity and potential for oxidation and methylation. Existing understanding of pathways and rates of bioaccumulation in aquatic environments permits coarse forecasts of exposure due to changes in MeHg inputs. This will help quantify the relationship between source reduction and risks to wildlife and people. Managing the problem in aquatic systems has largely focused on provision of fish-consumption advice for sport fishes to reduce human exposure, and on identifying upstream sources of mercury that can be quarantined or cleaned.

Mercury that has moved into anoxic environments with abundant organic material, such as lake bottoms, streams, and wetlands can present significant health risks and management challenges. Mercury extraction from these environments is ecologically disruptive. High rates of methylation in these environments depend less on mercury concentrations than on other factors, including sediment chemistry, salinity, hydroperiod, and microbial community composition, any of which can vary greatly at small scales of space and time. Depending on habitat characteristics, a greater or lesser proportion of the methylmercury produced in these environments will be available for uptake and transfer into wildlife and people.

Development of a comprehensive monitoring program, focused on the fish that people and wildlife target for consumption, including assessment of untested water bodies and ongoing trend monitoring at representative index locations, will provide the key overall performance measure for the system and its constituent regions. Linked biosentinel monitoring, using appropriate lower trophic level fish and invertebrates, will provide sensitive measures of spatial and temporal variability in methylmercury exposure, which can be used to help identify sources and track the outcomes of individual restoration and remediation projects.

Resource managers need to know how the mercury problem can be managed. One obvious need is to see if methylation and subsequent bioaccumulation are due to isolated hotspots or more ubiquitous and manageable factors, such as wetland types, plant cover types, substrate types, or hydrological regimes. The effects of such manageable factors on methylation rates and net bioaccumulation merit scientific study.

Resource managers and scientists should work more closely together to develop habitat designs and management practices that could minimize the mercury problem. Sharing responsibilities for proposal writing, research, and adaptive management will nurture the needed collaboration.

RMP 2005 Overview

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Bay from PCB contamination. The third study will identify new sampling locations in local watersheds.

Another special study this year will quantify the importance of dredging to contaminant bioaccumulation in the San Francisco Bay food web. The study will build a conceptual model of contaminant transfer to benthic-foraging fish species from dredging activities, including in-Bay disposal, and identify the steps necessary to estimate the contribution of dredging activities to contaminants detected in fish.

The toxic effects of contaminants is an important area that will be addressed through several RMP program elements in 2005 including the Episodic Toxicity program and the Exposure and Effects Pilot Study. Supplemental funding was obtained to expand an evaluation of the impacts of changing pesticide usage (i.e., phasing out of chlorpyrifos and increased use of pyrethroids) in urban and rural watersheds in tributaries around the Bay. The first round of sampling occurred in November 2004; the second will occur in April 2005.

The Exposure and Effects pilot study (EEPS) represents a second area of study on the effect of contaminants on the Bay. Potential elements of the EEPS for 2005 include: an analysis of diving ducks for selenium, mercury, and organochlorines; a field study of mercury risks to clapper rails; funding of research on fish effects; and an assessment of sediment toxicity, benthos, and sediment chemistry. It is anticipated that the Exposure and Effects Workgroup will meet in early 2005 to finalize this plan.

This year, the RMP and CEP are jointly funding a study of polybrominated diethers (PBDEs). The project will consist of a literature review to develop a conceptual model of the sources, pathways, and loading of PBDEs. Funds from the RMP will allow for field sampling of select matrices to fill important information gaps.

In other respects, the Program will continue on the new course (i.e., the spatially-randomized sampling design) begun in 2002. Water and sediment will be sampled at a new set of locations as the RMP continues to fill in a picture of the spatial distribution of contamination in the Bay. Under the new management objectives, the RMP for 2005 will continue to strive to provide scientists, regulators and interested stakeholders with relevant data and timely research that provide a sound foundation for management decisions.

Non-Point Source Pollution

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in the Bay: polychlorinated biphenyls (PCBs) and mercury (Hg). The storm water contaminant loading estimates have evolved over the years as we have refined the state of knowledge of NPSs and their magnitude in contributions of contaminants to the Bay (**Figure 1**). Preliminary estimates of urban storm water mercury loading in the beginning stages of TMDL development were about 119 kg/year (Abu-Saba and Tang, 2000). The estimate from the Guadalupe River watershed (containing the historic New Almaden mercury mining district) was approximately 49 kg/year. Recent research on the Guadalupe River watershed (see San Francisco Estuary Project 'Estuary Newsletter', Winter 2005) has resulted in better estimates of mercury loading from the old mining district. In the final TMDL, the New Almaden Hg mining district loading estimate is 92 kg/year (Looker and Johnson, 2004). A TMDL is being developed separately for the Guadalupe River watershed due to its significance as a mercury source to the Bay.

Figure 1 highlights the evolution of knowledge in quantifying mercury sources to the Bay. Current urban storm water loading estimates (which include both urban and the mining district contributions) account for approximately 46% of mercury inputs to the Bay (Lester McKee, pers. comm., 2004). The current estimate has more than doubled since the earlier estimate of 20%. The increase in the percentage contributed by urban storm water and the mining district as mercury sources has been mirrored by a decrease in the percentage of the California Central Valley as a mercury source. Loading estimates will continue to be revised as more scientific knowledge is gathered by the RMP over the next 5 years.

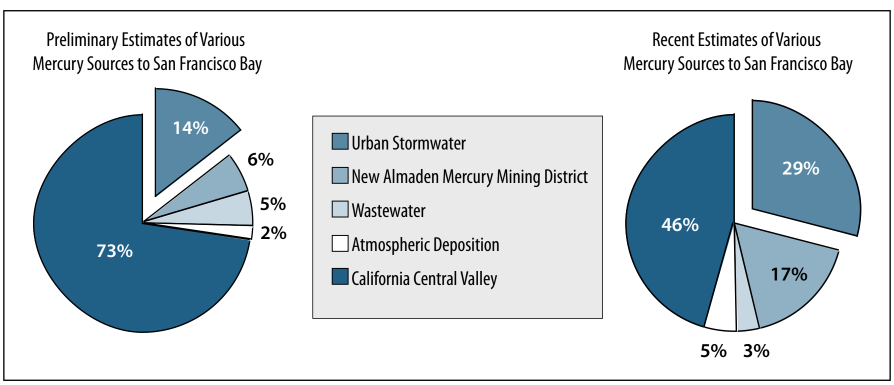

Figure 1. Preliminary estimates of various mercury sources to San Francisco Bay (Abu-Saba and Tang, 2000) compared with recent estimates (Looker and Johnson, 2004; Lester McKee, pers. comm.)

Best Management Practices – Reducing Contaminants in Storm Water Runoff

The Regional Board began regulating storm water runoff in the early 1990s and has since taken proactive measures

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to decrease the amount of contaminants entering the Bay in storm water. Discharge permits are given to the nine Bay Area counties in the San Francisco Regional Board's jurisdiction as well as industry and construction projects within the nine counties. Each permit holder is required to develop and implement a Storm Water Pollution Prevention Plan (SWPPP) that includes Best Management Practices (BMPs). BMPs are measures that aim to reduce the amount of contaminants entering the Bay from NPSs and include both educational outreach programs and physical processes. Citizen creek restoration groups, storm drain stenciling, and educational programs on alternatives to chemical pesticide use are a few of the BMPs that have been developed locally to reduce contaminants in storm water. Some of the physical processes include sediment removal from drainage lines, channel de-silting, and sediment removal from storm drain facilities. Since many high priority contaminants (PCBs, mercury and some pesticides) have a high affinity to adsorb to fine sediment particles, BMPs that remove fine sediment may also decrease the amount of contaminants that enter the Bay.

One of the main objectives of the RMP is to describe the main sources and transport mechanisms of contaminants to the Bay. The Watershed Program also at the San Francisco Estuary Institute (SFEI) works closely with the RMP to identify contaminant sources in Bay watersheds. Many of the tributaries around the Bay are sources of mercury to the Bay (see *RMP News* Fall, 2004). The next piece in the contaminant puzzle is to look more closely at the methods currently in use to reduce the amount of contaminants loading into the Bay. The Watershed Program has received funding from the Regional Board to assess the efficiency of BMPs in the removal of contaminants from storm water runoff. This project is a collaboration with the Bay Area Stormwater Management Agencies Association (BASMAA) and was funded through Proposition 13. This work will involve a review of current BMPs utilized and an evaluation of the efficiency of these BMPs. The efficiency evaluation will have both a 'desktop' component as well as a field component. The project will also aim to determine if the removal of sediment facilitates the removal of contaminants. This study will aid the Regional Board and BASMAA to identify the most effective BMPs for PCBs and mercury and therefore maximize contaminant removal from storm water.

Physical Characteristics of Contaminants in Storm Water

For both PCBs and mercury, fine sediment is the most likely mode of transport in storm water runoff. As mentioned earlier many BMPs remove sediment from storm water runoff as a proxy for removing contaminants. Contaminants such as PCBs and Hg have varying affinities to bind with organic matter and sediment particles. Binding affinity is dependent on many variables including concentration of sediment, pH and salinity. Generally, PCBs are hydrophobic and are relatively resistant to dissolving in water and their affinity to bind to organic material/sediment complexes is relatively high. This organic material/sediment complex is the main transport agent for hydrophobic contaminants in aquatic systems with high organic carbon and suspended sediments (McKee et al., 2003). It is generally held that aquatic systems with lower suspended sediments and organic carbon transport more of the PCB mass in the dissolved phase. Most of the creeks and streams that drain runoff in the nine county Bay Area have relatively high suspended sediment concentrations during storm events (McKee et al., 2003). Mercury also has a high affinity for binding to sediment particles particularly at higher suspended sediment concentrations.

> The ultimate goal in understanding chemical fate is to quantify the potential for bioaccumulation of contaminants in wildlife and humans and to determine the links between contaminant accumulation in living organisms and potential effects.

BMPs in Action

There are two main ways storm water agencies and municipalities are reducing the amount of contaminants entering the Bay via storm water runoff: source control and treatment control BMPs. Source-control BMPs act to reduce contaminants at their source while treatment-control BMPs remove contaminants from storm water after the contaminant has been mobilized. Source-control measures include landscape design that increases the amount of pervious ground for filtration, erosion and sediment controls, recycling, toxic site remediation, and educational outreach on alternatives to toxics use. Treatment-control measures include, for example, retention ponds, rain gardens, and vegetated swales (**Figures 2** and **3**). These engineered systems vary in their efficiency to remove fine sediment and which contaminants they remove from storm water but all are designed to filter sediment and decrease the amount of contaminants entering the Bay. The California Stormwater Quality Association (CASQA) has targeted four general areas for implementation of BMPs: new development and redevelopment, construction, industrial/commercial, and municipal.

Many of the storm water contaminant removal systems are localized engineering projects that can be developed on small scales. Retention ponds gather storm water and allow suspended sediments to settle out. If irrigation is combined with retention ponds then storm water is spread over land via irrigation systems and allowed to infiltrate the soil or other substrate. Vegetated swales are shallow, slightly sloping, vegetated channels that slow the movement of storm water to drainage points. Swales are designed to remove suspended sediments and are usually utilized in low flow areas. Media filters are two chambered systems where the first chamber is a pre-treatment settling basin and the second chamber contains sand or some other filtering media. Rain gardens are landscape designs that filter rooftop runoff (CASQA, 2003). These systems utilize various types of substrate to move storm water through with the goal of removing any contaminants sorbed to sediment. These systems can be combined for more effective storm water treatment.

From Sources to Fate: Contaminant Movement and Assessment in the Bay

One of the main areas of RMP focus has been on the fate of chemical contaminants once they enter the Bay. The ultimate goal in understanding chemical fate is to quantify the potential for bioaccumulation of contaminants in wildlife and humans and to determine the links between contaminant accumulation in living organisms and potential effects. The RMP has already completed a single box model which predicts how long it will take for PCB concentrations in fish to reach safe levels for consumption by humans and wildlife. The predictions have some uncertainty since it treats the entire Bay as one system that operates under the same conditions. We know that the Bay is a complex system that has many variables (salinity, contaminant concentrations, and sediment characteristics) that change on differing spatial and temporal scales within the Bay. The RMP is currently developing a multi-box model that divides the Bay into 52 sections with each box having a set of variables unique to each segment. The multi-box approach allows for the inherent variability of the Bay to be incorporated into the prediction of future PCB concentrations in the Bay based on current loading scenarios from all sources. Contaminant fate in the Bay and the potential effects of contaminants on wildlife is a growing focus of the RMP. SFEI staff are working with other organizations on developing statewide sediment quality guidelines. These guidelines will establish sediment contaminant concentrations that are targets for reducing the bioaccumulation of these contaminants in wildlife and humans to acceptable levels.

Reducing contamination in the Bay demands a multi-faceted approach. The early years of the RMP focused on identifying and quantifying the chemical contaminants in the Bay's water, sediment, and wildlife. With this knowledge the next step was to identify contaminant sources both within the Bay and in the watersheds of the Bay and quantify the loadings from these sources. The TMDL reports have utilized the most current state of knowledge on PCB and Hg sources including NPSs. The next task is to try to reduce the amount of contaminants at the source. Local storm water agencies and municipalities have developed both educational and engineering programs to help reduce the amount of contaminants that enter the Bay. The upcoming BMP study will provide new information to help identify those BMPs that will be most effective in reducing contaminant loading from non-point sources.

California Stormwater Quality Association (CASQA)

Figure 2: A vegetated swale designed to slow the movement of storm water and filter out sediments in storm water.

California Stormwater Quality Association (CASQA)

Figure 3: A landscaped rain garden acts as a filter of runoff from rooftops and other impervious substrates.

For further information on this study contact Lester McKee at lester@sfei.

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Endocrine Disrupting Chemicals
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The levels of these chemicals in the Bay generally fall below U.S. EPA established water quality criteria that are designed to protect humans from cancer and marine life from toxicity (U.S. EPA, 2000). There are currently no explicit water or sediment quality criteria for protecting human and marine life against endocrine system disruption and its related effects (e.g., reproductive defects or diseases, thyroid dysfunctions, and infertility). Modes of action of EDCs might include mimicking natural hormones, interfering with hormone function, interfering with uptake processes in target cells, and degrading hormones.

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EDCs in the Bay

The presence of hormonally active chemical contaminants in aquatic systems is an issue of concern. The tendencies of 4-nonylphenol, PBDEs, and the plasticizer di(2-ethylhexyl)phthalate (DEHP) to bioaccumulate and disrupt endocrine system functions further increases concern over their occurrence in the Bay. 4-Nonylphenol is primarily used as a precursor in the manufacture of surfactants that are commonly used in household detergents such as Simple Green® and as major components in herbicide formulations such as Roundup® and Aquamaster™. 4-Nonylphenol is also a breakdown product of these surfactants. In 2002, the RMP reported 4-nonylphenol in Bay water (range from 5 to 73 ng/L) and in one bivalve tissue sample (oyster 22 ng/g dry wt), but it was not detected (<5 ng/g) in sediments.

Phthalates are also a class of chemicals believed to be potential endocrine disrupters. One type of phthalate, DEHP, which is also a carcinogen, is a common contaminant in the Bay. This industrial compound is widely used in plastics in industrial products such as nitrocellulose, polyvinyl chloride (PVC), adhesives, and coatings, and in personal care products such as hair spray, fingernail polish, and cosmetics. In 2002, the RMP reported that DEHP concentrations in sediments ranged from 208 to 605 ng/g dry wt and in bivalves it ranged from 84 to 558 ng/g dry wt. A DEHP concentration (372 ng/L) was reportable in only one water sample due to problems with laboratory contamination.

PBDEs were recently reported in environmental and bivalve samples collected from the Bay (Oros et al., 2005). In 2002, the total PBDE concentrations in water samples ranged from 3 to 513 pg/L, while in sediments they ranged from below detection limits to 212 ng/g dry wt, and in bivalves from 9 to 106 ng/g dry wt. PBDE concentrations in the Bay appear to be increasing rapidly.

EDC Effects in Wildlife

Linking a specific contaminant or class of contaminants to biological effects in humans and wildlife is difficult. Laboratory tests can show links between specific doses of contaminants and effects but direct causation is difficult to prove in wild populations. 4-Nonylphenol is an estrogenic compound meaning that this chemical may mimic the role natural estrogen plays in human and wildlife physiology. In male fish, estrogenic chemicals can induce synthesis of vitellogenin, a compound that is a precursor to egg yolk that normally does not occur in male fish (Arcand-Hoy et al., 1998). Vitellogenin production in males has been observed in studies of wild fish from many ecosystems and has also been used as an indicator of fish exposure to endocrine disrupting chemicals (Christiansen et al., 1998; Hansen et al., 1998). However, the significance of this vitellogenin production relative to the reproduction, growth, and survival of male fish is unknown. Laboratory studies on endocrine disrupting chemicals have shown effects such as abnormal fin development in male Japanese medaka fish (Tabata et al., 2001), reproductive abnormalities in male rats (Gray et al., 1999), and testicular abnormalities in male offspring of female rats. The potential population level effects of endocrine disrupting chemicals on wildlife are still poorly understood.

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Future Challenges

Research is needed to better understand the underlying effects, exposure, assessment, and risk management of endocrine disruptors in aquatic systems. This includes determining dose-response relationships in aquatic species, the effects of exposure to multiple endocrine disruptor compounds, major sources and pathways of exposure, and approaches for managing risks. Equally important is focused research to better understand the extent of the impact of endocrine disruptors on humans and wildlife, including aquatic biota. This includes relating effects at subcellular levels to effects at individual and population levels and extrapolating effects from one animal species to another and to humans. For instance, this could be done by combining in vivo assays with computational models to determine population effects. From a management perspective, steps could still be taken to mitigate unreasonable risks of exposure. The RMP is funding a Pilot Study in 2005 that will begin to look at the linkages between chemical contaminants, including endocrine disruptors, found in the Bay to effects in Bay fish.

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2005 RMP Annual Meeting

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What can we do to improve the RMP News?

This RMP News Questionnaire may also be completed online: www.sfei.org

Does the RMP newsletter keep you informed about environmental science and management in San Francisco Bay?

__Yes
__No
__Other/Comment ____________________

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Does the newsletter have an appropriate balance between science and management?

__Yes, the relationship of science to management is important
__No, the RMP newsletter should focus more on the science of the Bay
__Other/Comment ____________________

____

Are newsletter articles written at an appropriate technical level?

__More technical content would improve the newsletter
__The content is at the appropriate technical level
__The articles are too technical
__Other/Comment ____________________

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Which of the following areas best describes your current occupation?

__Environmental Manager
__Scientist
__Engineer
__Teacher
__Media
__Other ____________________

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Other comments or suggestions are welcome below.

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