

*Item #6*

**SOURCES, PATHWAYS, AND  
LOADINGS: FIVE-YEAR WORK PLAN  
(2005-2009)**

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### Recent Workgroup Attendance

March, 2004	October, 2004	May, 2005
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Andy Jahn, Port of Oakland	Andy Gunther, AMS	Terry Cooke, URS
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## SUMMARY

*This work plan has been written to help direct the activities of the Sources Pathways and Loadings Work Group over the period 2005-09 (the second 5-year period of its existence). The work plan is not meant to be prescriptive or rigid but rather provide a living document that can be updated by annual revisions of the Gant Chart (Table 4). The work plan presented follows a typical format for such documents - summarizing previous activities and achievements, presenting objectives and management questions, discussing funding barriers, and providing some examples of external activities that will influence SPLWG work products over the next 5 years. This information is used as a basis for justification and prioritization of SPLWG activities in relation to SPLWG management questions. The Gant Chart at the end of document presents specific projects and funding allocations for projects that help to address the prioritized activities. This Chart will be updated periodically as new studies are proposed and developed through the Workgroup process and approved by the Technical Review Committee of the Regional Monitoring Program.*

## INTRODUCTION

The Regional Monitoring Program for Traces Substances (RMP) is an innovative collaborative effort created in 1993 between the San Francisco Estuary Institute (SFEI), the San Francisco Bay Regional Water Quality Control Board (RWQCB), and the regulated discharger community. The aim of the RMP is to develop and improve the understanding of contaminant impacts on the beneficial uses of San Francisco Bay through monitoring, research and communication. In 1997 the RMP underwent a five-year program review which helped to develop a revised set of RMP objectives including a new objective: "Describe general sources and loading of contamination to the Estuary" (Bernstein and O'Connor, 1997). The hope was to create a functional connection between the RMP and efforts to identify, eliminate, and prevent sources of pollution that influence the Bay. At the same time, SFEI was developing the Watershed Science Approach (WSA) in the context of its new Watershed Program (Collins et al. 1998). A main objective of the WSA was to help characterize local watersheds in terms of their sources and conveyance of sediment and water, based on the hypothesis that local watersheds significantly influence the quantity and quality of sediment along the margins of the Bay. The WSA also called for long-term monitoring of a regional network of local watersheds. In its review of the WSA, the Regional Board termed these "Observation Watersheds," the establishment of which became a common objective of the RMP and the Watershed Program at SFEI. Together, SFEI and the Regional Board prioritized the creation of digital maps of local drainage systems including storm drains as a critical step in watershed characterization.

The Sources, Pathways, and Loading Workgroup (SPLWG) was formed in early 1999 to develop a vision for the collection, interpretation, and synthesis of data on general sources and loading of trace contaminants to the Estuary. The initial SPLWG recommendations were described in the first "Technical Report of the Sources Pathways and Loadings Workgroup" (Davis et al., 1999). Since that time the SPLWG has continued to provide management context and technical review on a series of desktop and field studies. The SPLWG ensures that the projects and products are relevant and help to

answer ever developing management questions in the context of TMDLs and attainment of water quality standards.

## 50 **SPLWG ACTIVITIES AND ACHIEVEMENTS TO-DATE**

A fundamental early product of the SPLWG was the development of a focus list of contaminants in the context of watershed sources. In 1999, the order of emphasis was highest for PCBs, PAHs, and organophosphate pesticides (OPs) (Table 1). By 2005 the emphasis had changed and polybrominated diphenyl ethers (PBDEs), endocrine  
55 disruptors, and pyethriods had been added. Scientific studies on sources, pathways, and loadings, the ongoing RMP monitoring of concentrations in the physical and biological components of the Bay, physical and food-web modeling, and an improved understanding of the relationship between contaminants and beneficial uses has helped to adjust the priority list.

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**Table 1.** The evolution of priority contaminants in the San Francisco Bay Region in the context of the SPLWG.

2000		2005	
PCBs	Top	PCBs and Hg	Top
PAHs	High	PBDEs	High
OPs	High	Endocrine disruptors	High
Hg	Medium	Pyrethroids	High
Se	Medium	Se	Medium
Cu	Medium	Cu	Medium
Ni	Medium	DDT, chlordane, dieldrin	Low
TBT	Medium	Ag, As, Cd, Cr, Ni, Pb, Zn	Low
Ag	Medium	Dioxins/Furans	Low
Cd	Medium	PAH hotspots	Low
Chlordane	Low	OPs	Low
DDT	Low		

65 In 1999 and 2000, the SPLWG oversaw the completion of a project titled: “Contaminant Loads from Stormwater to Coastal Waters in the San Francisco Bay region: Comparison to other pathways and recommended approach for future evaluation” (Davis et al., 2000). Davis, McKee, Daum, and Leatherbarrow collated existing  
70 information on stormwater contaminant concentrations found in the urban storm drains and creeks tributary to San Francisco Bay. They used a simple model based on land use, rainfall, and estimated runoff generated using runoff coefficients, to estimate loadings based on land use specific concentration data where they existed. Loadings in stormwater runoff for suspended sediments, cadmium, chromium, copper, lead, nickel, and zinc were estimated. However, Davis et al. were not able to estimate loadings from the stormwater  
75 pathway of several contaminants of interest including PCBs, mercury, PAHs, pesticides, and selenium. They also presented loadings for suspended sediments, cadmium, chromium, copper, nickel, and zinc for the other pathways (wastewater, atmospheric deposition, and dredge material) and made comparisons between these and estimated loadings entering the Bay via the Delta from the Sacramento and San Joaquin Rivers. A refined and more detailed set of recommendations was perhaps the most important  
80 contribution made by Davis et al. (2000) (Figure 1). These recommendations, built on those of Davis et al. (1999), became the guiding philosophy of the SPLWG for the past 5

years and are the starting point for the development of the 5-year work plan presented here. Although these are great guiding principles, they lack specificity for each  
 85 contaminant. For example, watershed characterization and classification for legacy  
 contaminants would likely focus on historic land use and use distribution and might  
 necessarily require a detailed understanding of hydrography in relation to heterogeneous  
 sources. Contaminants with large atmospheric pathways and/or ubiquitous use might  
 require little or no watershed characterization. In terms of conceptual models, these might  
 90 be relatively simple or very complex depending on the contaminant and might be well  
 founded in scientific literature or in the case of some of the emerging contaminants,  
 undergoing basic scientific development in the areas of phase partitioning, breakdown  
 derivatives, half lives, attenuation, or even source distribution. These things said, the  
 recommendations in Figure 1 remain valid today and will help guide the SPLWG  
 95 throughout the next 5 years.

**Figure 1.** Sources Pathways and Loadings Work Group (Davis et al., 2000).

- |     |  |
|-----|--|
| 100 | A. <b>Watershed Characterization:</b> Characterize and classify the watersheds in the region with regard to factors that control stormwater transport of priority contaminants.                            |
|     | B. <b>Conceptual Model Development:</b> Develop conceptual models for the generation, distribution, transformation, transport, and effects of classes of priority contaminants.                            |
|     | C. <b>Develop Evaluation Strategies:</b> Design and implement appropriate evaluation strategies for classes of contaminants with similar properties.   |
| 105 | D. <b>Establish Regional Network of “Observation Watersheds”:</b> Carefully select representative “Observation Watersheds” for detailed, long-term evaluation of stormwater loading and related functions. |
|     | E. <b>Extrapolate to Other Watersheds:</b> As appropriate, extrapolate results from the Observation Watersheds to other watersheds with similar characteristics.   |

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Following early recommendations by the SPLWG (Davis et al., 1999), in 1999, 2000, and 2001, the SPLWG oversaw a study on atmospheric deposition of mercury (Tsai and Hoenicke, 2001), copper, nickel, cadmium, and chromium (Tsai et al., 2001), and PAHs and PCBs (Tsai et al., 2002). These studies confirmed that the mass loadings  
 115 of these metals and chemicals to the watershed and to the Bay directly from the air  
 pathway were small compared to other pathways such as the large rivers and stormwater  
 except in the case of mercury where atmospheric deposition may account for about one  
 third of the estimates of stormwater load. At the completion of these studies, the SPLWG  
 recommended that periodic monitoring be continued at just one station to trace trends and  
 120 measure atmospheric deposition of other contaminants as necessary. Given that several  
 new pollutants (PBDEs, endocrine disruptors, and pyrethroids) have been added to the  
 list of priority contaminants, atmospheric deposition studies may increase in importance  
 again as conceptual models for these substances are developed.

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Following recommendations in Davis et al. (1999, 2000), in 2001 and 2002, the SPLWG oversaw the development of two watershed characterization efforts (Figure 1: Recommendation A). The first was a map of PCB concentrations in sediment of the Bay and its watersheds <http://www.ecoatlas.org/custom/pcbtool.html>. This was used to further  
 130 discussions and helped develop sampling strategies for contaminant concentrations in the  
 bed sediment of urban drainages (Gunther et al., 2001; KLI, 2002). The second effort

aimed to collate existing information on storm drain infrastructure in the Bay Area and make recommendations on how to compile a regional scale map of drainage lines and watershed boundaries (Wittner and McKee, 2002). This report concluded that digital storm drain data are not available in the Bay Area on a regional scale. Data in city and county jurisdictions are mostly stored on paper maps and in a variety of CAD packages and GIS data formats, are mostly not updated recently let alone systematically, and are commonly without data quality indicators or any other form of metadata often because of staff turnover and/or lack of resources. Wittner and McKee (2002) recommended that there be regional support and funding for the methodology being developed and implemented by the Oakland Museum of California and WLA that produces creek and watershed maps showing storm drains larger than 24 inches and watershed boundaries. To-date (November 2005) there have been eight maps completed in this series (for details speak to Janet Sowers, WLA or Christopher Richard, OMC) and there are four more in production. The only major gaps on the Bay margin are the cities of Marin, and the Vallejo, Benicia, and Fairfield/Suisun areas. These maps provide a valuable tool for understanding the relationship between sources of contaminants, transmission through drainage systems, and loading to the Bay. They will form an important input data set for proposed future watershed contaminant modeling. That said, we presently have no mechanism in place for regular updates, an issue that is important in industrial areas undergoing redevelopment and in urbanizing areas.

In 2000, 2001, and 2002, the SPLWG oversaw the interpretation of data collected in the “Estuary Interface Pilot Study” (Leatherbarrow et al., 2002). This report demonstrated that water and sediment concentrations were highest on the Bay margins relative to other parts of the Bay, strongly indicating a gradient of increasing concentrations of Hg, PCBs, and OC pesticides up the salt to freshwater gradient. This report also discussed artifacts caused by the normalization of bulk sediment contaminant concentrations to “% fines” (the fraction of sediment <0.0625 mm). However, the SPLWG never developed a consensus recommendation on how to proceed on this issue mainly because it was felt that the cost of making measurements on specific grain sizes was prohibitive. In addition, the method used to differentiate particle sizes in the lab may introduce handling artifacts if method physics and chemistry causes the breakdown of particle aggregates or causes adsorption or desorption. Literature review and perhaps even method development and validation are required to resolve these questions. In the case of organic trace contaminants and even some metals, it might be better to normalize to organic carbon. This issue will likely be revisited again when the BASMAA agencies storm drain sediment data (Salop et al., 2002; KLI, 2002) is reinterpreted during the SFEI Prop 13 project (See discussion below). Leatherbarrow et al. estimated loadings of Hg for the Guadalupe River based on data collected in Alviso Slough and strengthened recommendations that a small tributaries loading study should be started to estimate loadings more accurately; a small tributaries loading study was started on Guadalupe River later in 2002 (McKee et al., 2004; McKee et al., 2005). The finding from this report suggest that local watersheds are an important sources of water, sediment, and contaminants to the Bay margin and that the importance increases landward from the from the Baylands foreshore.



Following a recommendation in Davis et al. (1999), in 2001, 2002, and 2003, the SPLWG oversaw the development of two literature review and data compilation efforts (Figure 1: Recommendation B & C). Data and literature were gathered to develop a methodology for estimating suspended sediment loadings entering the Bay via the Delta from Central Valley during “large resuspension events” (McKee et al., 2002). Available data at that time spanned the period from water year 1995-98 (4 years). The authors presented a hypothesis that the average load of suspended sediment was ~1 million metric tonnes annually or about 2.5x less than previous estimates. They suggested that the local urban watersheds were likely a larger contributor to the overall Bay sediment and contaminant budgets than had previously been thought. The report also linked the erosion in the Bay to a decrease in Delta sediment throughput and recognized a variety of implications of this load reduction, including less dredging, mobility of legacy contaminants due to Bay scour, and less suspended sediment for restoration projects. The report recommended that a study be conducted to collect trace contaminant concentration data during floods at Mallard Island on the Sacramento River (This study began in January 2002: Leatherbarrow et al., 2004). The second literature review and data compilation effort developed conceptual models of runoff processes in urban watersheds of the Bay Area (McKee et al., 2003). It included extensive review of rainfall and runoff data for the Bay Area. It also included a compilation of local suspended sediment data collected by the USGS over the past 40 years and used to this to make estimates of suspended sediment loadings from the local small urbanized tributaries. The report reviewed recent literature on PCBs, OC pesticides, and Hg in watershed environments and made recommendations on how to sample urban stormwater runoff in urban tributaries of the Bay Area.

In 2002, the first loadings field monitoring project overseen by the SPLWG was started at Mallard Island on the Sacramento River in collaboration with UCSC and USGS following the recommendations of McKee et al. (2002) (Figure 1: Recommendation D). The first report on this data was presented to the SPLWG in 2004 (Leatherbarrow et al., 2004). This report documented nine years of suspended sediment loadings and proved that the long-term average is ~1M metric tonnes annually. The report also presented mercury, PCB, OC pesticides and PAH loadings for WYs 2002 and 2003 and recommended that further evaluation be done to document loadings during “Yolo bypass events” at flows exceeding the magnitude already sampled (160,000 cfs). This is particularly important for the transport of mercury given the Yolo system in the receiving water body for the contaminated Cache Creek watershed. The sediment section has been accepted for publication in the Journal of Hydrology (McKee et al., in press). The SPLWG recommended that the study be continued using a combination “opportunistic” and “periodic” sampling strategy. The SPLWG also recommended that the variation in the cross-section be quantitatively determined during base and flood flow. To achieve this we have embarked on collaboration with the Region 5 RWQCB (C Foe) and the USGS in Sacramento (N Ganju and D Schoellhamer). To-date, we have completed the evaluation for flows <60,000 cfs.

Between 1999 and 2003, SPLWG recommended funding for two USGS efforts to better quantify the release of metals from bottom sediments in the Bay. The first of these

studies reviewed knowledge about nickel sources to the Bay (comparing and contrasting nickel sources with copper sources) and addressed questions regarding nickel release from South Bay sediments (Topping and Kuwabara, 2003). The results indicated that benthic flux of nickel is significant relative to both wastewater and stormwater inputs and likely a primary process for controlling dissolved nickel concentrations in the water column during the majority of the annual cycle. The second study, also conducted in South San Francisco Bay, quantified dissolved mercury fluxes to the water column from bottom sediments (Topping et al., 2004). The study results from three locations, when extrapolated for the entire South Bay supported the conclusion that dissolved fluxes to the South Bay water column may be of the same magnitude as annual inputs from the Guadalupe River watershed.

In WY 2003, following recommendations by Davis et al. (2000), the first “small tributaries loading study” was begun with funding from the Clean Estuary Partnership (CEP) (Figure 1: Recommendation D). This study continued in WYs 2004, 2005, and 2006 with funding from the CEP, RMP, United State Army Corps of Engineers (USACE), the Santa Clara Valley Water District (SCVWD), and the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP). So far data from the first three years have been interpreted (McKee et al., 2004; McKee et al., 2005). In WY 2005, the data collection effort was expanded to include methyl-mercury, bedload sediment Hg, and PBDEs. There have been some major outcomes from this study so far. These include 1. Concentrations of PCBs up to 90,000 pg/L during storms (these are some of the highest concentrations ever measured in an urban watershed in the world although it should be kept in mind that methods used influence results comparability), 2. PCB loadings from this one watershed alone are in excess of 1 kg/year and may influence recovery times substantially (Davis, 2004; Leatherbarrow et al., 2005), 3. Total Hg concentrations up to 19 µg/L (concentrations this high far exceed those normally found in urban systems and are typical of mining impacted systems such as the Guadalupe River), and 4. Measured loadings of 116 kg (WY 2003) and 15 kg (WY 2004). In addition McKee et al. (2005) made a hypothesis of long-term average annual load (157 kg) with a range from 0.026 kg in very dry years to 1,070 kg in a water year like 1983. Further, they hypothesized that the average loadings over each 5-year period would be expected to vary from 6.2-443 kg or about 4%-282% of the estimated annual average load (157 kg).

The data and interpretations presented in a mounting list of reports recommended and overseen by the SPLWG have caused some major changes in our perception on the way San Francisco Bay functions. For example, in 2000 it was thought that 80% of the suspended sediments entering the Bay annually were derived from the Central Valley; our present hypothesis is now closer to 60:40 (Central Valley: Small Tributaries in the nine-county Bay Area). In 2000, it was thought that the majority of allochthonous Hg and PCB load was also derived from the Central Valley; we now (March 2005) estimate the ratio to be about 50:50 (Central Valley: Small Tributaries in the nine-county Bay Area) for both substances. These findings have wide reaching implications for management initiatives that aim for improvement of the water quality of the Bay; the collective SPL studies have played an important role in the development of TMDLs for Hg and PCB (Looker and Johnson, 2004; Hetzel, 2004). To complete the circle of adaptive

270 management, implementation actions recommended by the TMDLs provide an emphasis  
for future SPLWG study efforts. For example, the Hg TMDL recommends:

1. *Evaluate and report on the spatial extent, magnitude, and cause of contamination for locations where elevated mercury concentrations exist.*
- 275 2. *Develop and implement a mercury source control program.*
3. *Develop and implement a monitoring system to quantify either mercury loads or the loads reduced through treatment, source control, and other management efforts.*

280 The Guadalupe Watershed received special attention in the Hg TMDL (Looker  
and Johnson, 2004) because of the history of Hg mining at New Almaden. The following  
implementation recommendations in the proposed revision of the Basin Plan also have  
implications for SPL activities:

1. *Quantify the annual average mercury load reduced by implementing:*
  - 285 i) *Pollution prevention activities*
  - ii) *Source and treatment controls, and*
  - 290 iii) *If applicable, other efforts to reduce methylation or mercury-related risks to humans and wildlife consistent with the watershed-based strategy. The Water Board will recognize loads reduced resulting from activities implemented after 1996 (or earlier if actions taken are not reflected in the 2001 load estimate) to estimate load reductions.*
2. *Quantify the mercury load as a 5-year annual average mercury load using data on flow and water column mercury concentrations.*
- 295 3. *Quantitatively demonstrate that the mercury concentration of suspended sediment that best represents sediment discharged from the watershed to San Francisco Bay is below the suspended sediment target.*

300 The PCB TMDL for San Francisco Bay is on a slower timeline relative to the Hg  
TMDL. The staff report (Hetzl, 2004) however, contains implementation  
recommendations similar in many ways to those of Hg and will similarly influence future  
SPLWG activities:

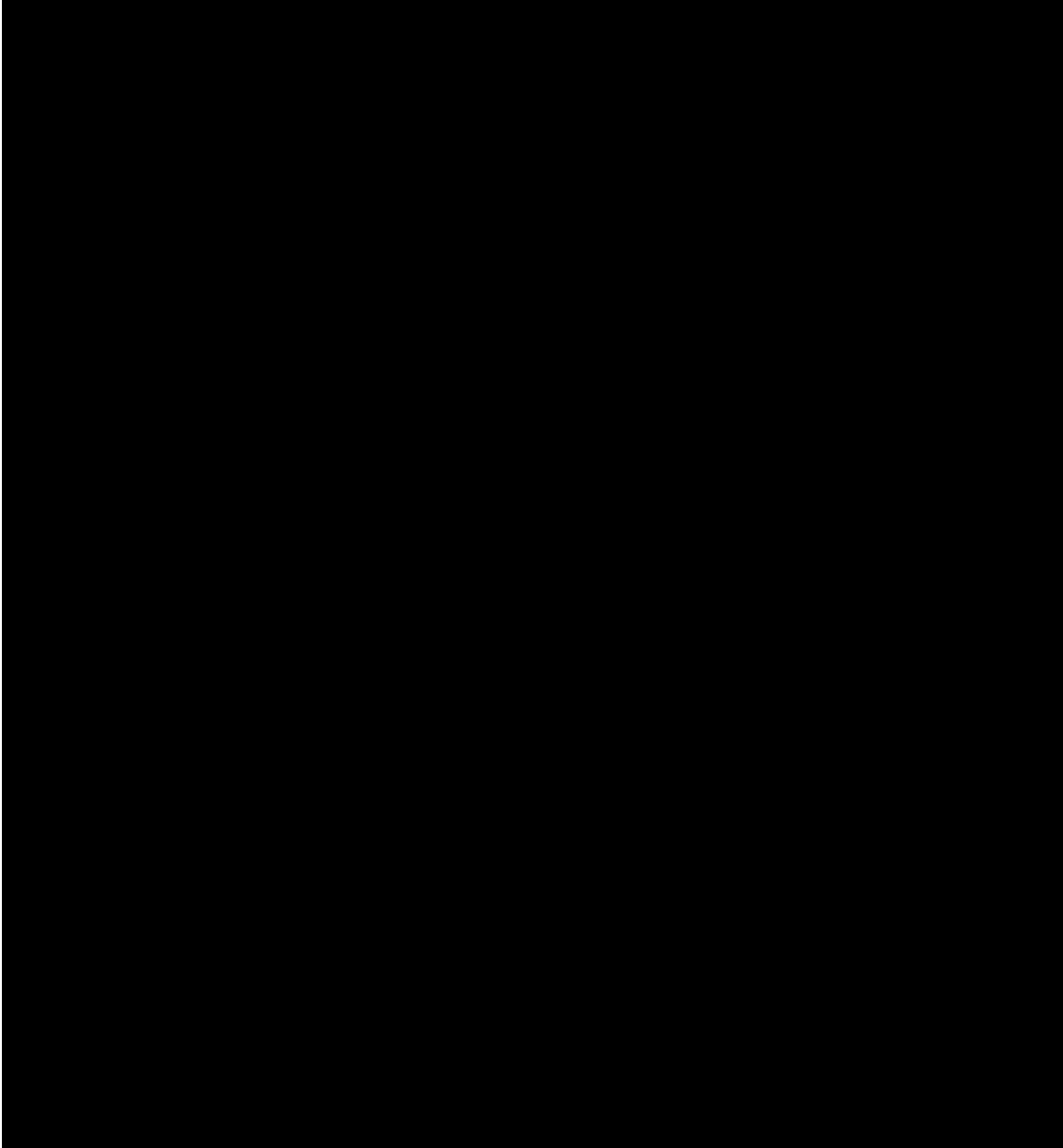
1. *Demonstrate attainment of the sediment target in discharges*
2. *Demonstrate load reductions in discharges*
- 305 3. *Demonstrate loads removed by actions taken that might include:*
  - i) *Cleanup of hotspots on land, in storm drains, and in the vicinity of storm drain outfalls*
  - ii) *Capture, detention, and treatment of highly contaminated runoff*
  - 310 iii) *Implementation of urban runoff management practices and controls that have PCBs removal benefit.*

The recommendations written into the Hg and PCB TMDLs suggest that studies  
overseen by the SPLWG should focus on estimation of loadings over 5-10 years in  
strategic watersheds where there are known Hg and PCB sources and where management  
activities are being applied specifically to try to reduce loadings. The starting date for  
315 such studies is funding dependant. It is well known that tributary loading studies need a  
long time series of data in order to determine the inter-annual variability, be it only from  
climactic variability. Since there are initial data for both Mallard island and the  
Guadalupe river and annual sediment loads for a number of other small tributaries in the  
Bay Area, it may be worth the effort to determine statistically the number of annual

320 samples and the number of sampling years needed to obtain various confidence levels for  
average annual loads and to be able to measure a decrease in loads.

Recently, the PCB workgroup of the CEP oversaw the development of a multi-  
box PCB model (Leatherbarrow et al., 2005) that built upon the single-box model work  
325 of Davis (2004). Improvements included a more spatially explicit set of loading functions  
from a variety of pathways, better modeling of remobilization from bed sediments,  
modeling of sediment mixing and tidal flushing, and spatially explicit modeling of Bay  
segments. There are plans to complete version 2 of that modeling effort in late 2005.  
Improvements in version 2 will include a better (separate) treatment of erosion and  
330 deposition, dynamic box volumes, dynamic changes to velocity and bed shear stress,  
improved spatial resolution of tributaries loadings with the exclusion of bed load, a  
dynamic Delta boundary that allows for sediment loss to the Delta, and improved  
treatment of erosion and deposition in the Lower Far South Bay box. Outcomes so far  
suggest that the Bay is sensitive to watershed loadings and that the southern parts of the  
335 Bay are most sensitive. This might suggest a prioritization of loadings studies in the  
South Bay, however this is inconsistent with the "Observation Watershed Approach"  
proposed by Davis et al. (2000) and still presently supported by SPLWG members. It is  
anticipated that the improvements in the model will provide further insight into the  
influence of small tributaries on recovery time for each of the segments; information that  
340 will provide context for SPLWG debate on activities and priorities.

The main tributaries of the South Bay include Alameda Creek, Coyote Creek,  
Guadalupe River, Stevens Creek, Permanente Creek, Adobe Creek, Baron Creek,  
Matadero Creek, San Thomas Aquino Creek, Calabazas Creek, and San Francisquito  
345 Creek (Figure 2). In addition there are numerous "storm drain tributaries" that enter the  
Bay directly (Sowers, 1999; Sowers, 2004; Sowers and Thompson, 2005). If we assume  
that during most years, no sediment and attached pollutants passes through reservoirs in  
the tributaries, the area associated with "storm drain tributaries" in the South Bay and  
Lower South Bay is ~6% of the total runoff producing area below reservoirs (Figure 2;  
350 Table 2). Further, if we assume a runoff coefficient of 60-80%, an average annual rainfall  
of 254-381 mm (10-15 inches) and a flow-weighted mean PCB concentration of 26-55  
ng/L (observed on Guadalupe (McKee et al., 2004; McKee et al., 2005), these minor  
"storm drain tributaries" alone might account for ~1.2 kg of PCBs annually (Table 3). It  
seems likely that concentrations in stormwater associated with "storm drain tributaries"  
355 on the Bay margin might be greater than we have observed in Guadalupe River because  
these tributaries drain areas that were formally or presently industrialized and in many  
cases, being urbanized through redevelopment. A better understanding of PCB  
concentrations and loadings in some of the minor "storm drain tributaries" would help us  
to understand how to extrapolate limited data across the Bay Area watersheds (Figure 1:  
360 Recommendation E) and provide data to measure success of management aimed at  
reducing loadings. In addition, future versions of the PCB multi-box model could  
incorporate more spatially explicit loading functions, or better still, develop an integrated  
watershed-Bay model. Such a model would allow the direct evaluation of the influence of  
management actions on both watershed concentrations and loadings, and the response of  
365 the Bay in terms of spatial water quality and change through time.



**Figure 2.** Small tributaries and “storm drain tributaries” entering the South Bay and Lower South Bay segments.

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Another recent study of interest to the SPLWG was titled “Analysis of pollutants in sediment cores near storm water inputs – final report” (AMS, 2004). This study concept was originally discussed by the SPLWG in 2001 and 2002 and then developed and implemented in the context of PCB removal with funding from the CEP. Sites on the Bay margin were selected based on the likelihood of near-field deposition of sediment with high PCB concentrations. Twenty six cores were analyzed in six locations. Two cores (one in San Leandro Bay and the other in Moffett Channel) showed concentrations higher than the rest and provide context for watershed loadings studies.

380

380 **Table 2.** Watershed and “storm drain tributary” areas of watersheds of the greater South Bay.

<b>Drainage name</b>	<b>Area (km<sup>2</sup>)</b>	<b>Area (mi<sup>2</sup>)</b>	<b>Drains via</b>
Adobe Creek	29	11	Creek
Agua Fria Creek	20.4	7.9	Creek
Alameda Creek	1,663	642	Creek
Arroyo de la Laguna	37	14	Creek
Barron Creek	8.0	3.1	Creek
Calabazas Creek	53	21	Creek
Coyote Creek	831	321	Creek
Coyote Hills West	1.0	0.4	Creek
Coyote Laguna	0.1	0.1	Creek
Guadalupe River	445	172	Creek
Lake Elizabeth Creeks	28	11	Creek
Lower Penitencia Creek	74	28	Creek
Matadero Creek	12.5	4.8	Creek
Permanente Creek	47	18	Creek
San Francisquito Creek	117	45	Creek
San Tomas Aquino Creek	115	44	Creek
Stevens Creek	78	30	Creek
Ardenwood Crandall Creeks	16.9	6.5	Storm drain
Coast Casey Forebay	3.6	1.4	Storm drain
Golf Course	1.8	0.7	Storm drain
Mallard Slough	6.7	2.6	Storm drain
Moffat West	2.8	1.1	Storm drain
Mowry Slough	32	12	Storm drain
Newark Slough	12.4	4.8	Storm drain
Plummer Creek	6.5	2.5	Storm drain
Salt Evaporators	3.1	1.2	Storm drain
Sunnyvale East	17.2	6.6	Storm drain
Sunnyvale West	18.6	7.2	Storm drain
Treatment Plant	0.6	0.2	Storm drain
<b>Summed Creek area</b>	<b><u>3,578</u></b>	<b><u>1,381</u></b>	
<b>Summed Storm drain area</b>	<b><u>122</u></b>	<b><u>47</u></b>	
<b>Total area</b>	<b><u>3,700</u></b>	<b><u>1,428</u></b>	
Del Valle Reservoir	373	147	
San Antonio Reservoir	102	40	
Calaveras Reservoir	354	139	
Anderson Reservoir	491	193	
Calero Reservoir	17.5	6.9	
Almaden Reservoir	30	12	
Guadalupe Reservoir	15.0	5.9	
Vasona Reservoir	112	44	
Stevens Creek Reservoir	44	18	
<b>Total reservoir area</b>	<b><u>1,539</u></b>	<b><u>606</u></b>	
<b>Total area minus reservoir area</b>	<b><u>2,161</u></b>	<b><u>822</u></b>	
<b>% draining via creeks</b>	<b><u>94.3</u></b>		
<b>% draining via storm drains</b>	<b><u>5.7</u></b>		

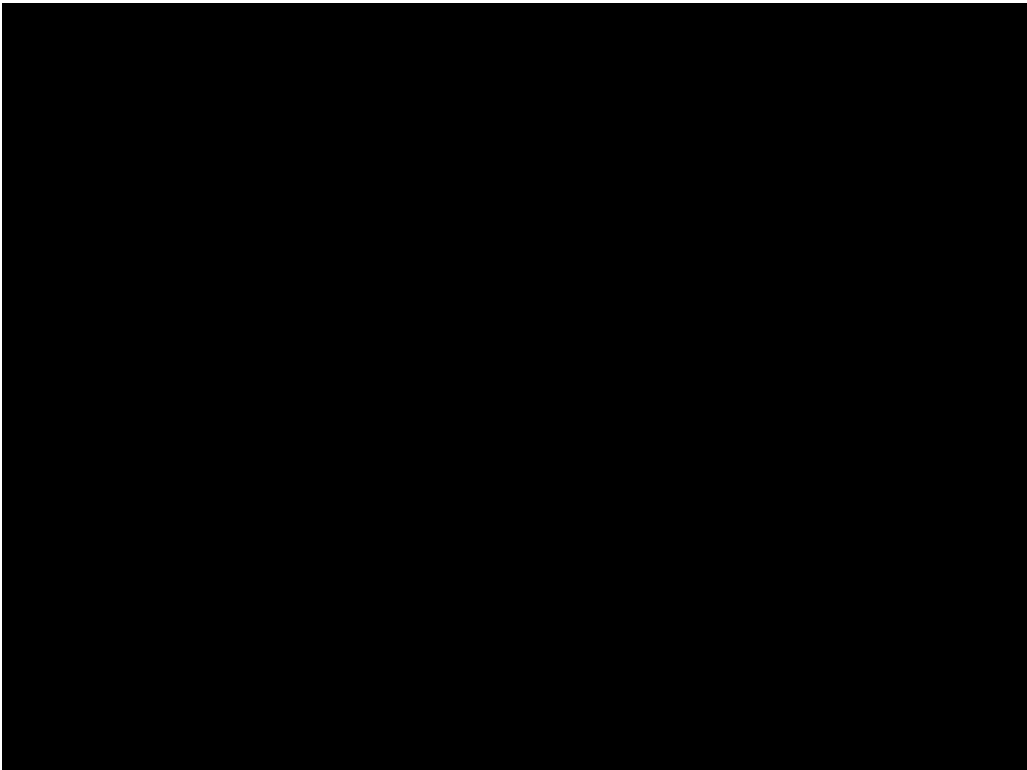
385 **Table 3.** Thought experiment on the PCB loading potential for minor “storm drain tributaries” that drain formally industrialized or presently industrialized areas.

	Area (km <sup>2</sup> )	Rainfall (mm)	Runoff Coefficient (%)	Runoff (Mm <sup>3</sup> )	PCB (ng/L)	Annual PCB load (kg)
Min	122.37	254	60	18.6	26	0.48
Max	122.37	381	90	42.0	55	2.31
Mean	122.37	318	75	29.1	41	1.18

390 SFEI recently performed a small reconnaissance survey of the Sausal Creek  
 outfall delta (Figure 3). At this location, we measured a minimum volume of sediment in  
 the delta of 5,900 m<sup>3</sup>. It is not known over what time period this delta has built up but our  
 casual observations suggest it has been getting larger over the past 3 years. It is likely that  
 significant tidal reworking occurs each year dispersing even the larger size fractions away  
 395 from the outfall point. It is likely that many of these deltas occur on the Bay margin  
 adjacent to storm drain outfalls. A screening level survey of a number of these deltas  
 including the measurement of volume, TOC, and grainsize could be used to develop a list  
 of priority sites. A detailed field study of 3-5 priority outfall locations over a wet season  
 would determine if removal is a viable option for improving water quality in the Bay.  
 400 This type of study could be completed along side a new small tributaries loading study to  
 gain an understanding of the portion of load that is stored in the delta.

There are a number of ongoing studies that will continue to provide information  
 that is relevant to the activities of the SPLWG. For example, SFEI received a Proposition  
 405 13 grant entitled “Regional Stormwater Monitoring and Urban BMP Evaluation: A  
 Stakeholder-Driven Partnership to Reduce Contaminant Loadings”. Although this project  
 as a whole has its own oversight structure, several tasks within the project were  
 recommended and developed by the SPLWG. Task 3.2: “Map of Natural and Urban  
 Drainage” will further our efforts to characterize the watersheds on the Bay Area (Figure  
 410 1: Recommendation A). The outcome of this task will be a completed contiguous map of  
 USGS natural rivers and creeks (“blue lines”) for the Bay Area, a compiled map of storm  
 drains and engineered channels (larger than 24 inches in diameter) and watershed  
 boundaries. The National Wetlands Inventory (NWI) of the USFWS is being updated for  
 the Bay Area through the Wetlands Program at SFEI to classify and map all wetlands,  
 415 lakes, and riverine systems in terms of their ecological form and water sources (Cowardin  
 et al. 1979, NWI 2002, Collins 2004). At the same time, the Wetlands Program is testing  
 new tools to assess wetland condition relative to natural variability and stressors at the  
 watershed scale (Brown 2005). The new NWI and the related tools to assessing wetland  
 condition will be helpful in monitoring the effects of watershed management actions.

420 Task 3.3 in our Prop 13 grant is to “Develop Methods for Extrapolation of  
 Spatially and Temporally Limited Datasets” was also developed and recommended by  
 the SPLWG. This task will analyze 40 years of USGS suspended sediment data to  
 determine trends and the causes of trends and determine if it is possible to extrapolate  
 425 data to non-gauged watersheds. Both of these tasks will provide important input data for  
 future modeling efforts that aim to improve regional scale loading estimates. Task 3.3



430

**Figure 3.** Sausal Creek outfall Delta located near the Fruitvale Avenue Bridge to Alameda. Note the prominent delta impinging on the shipping channel at this location.



will be completed in September 2005 and Task 3.2 will be completed in December 2006.  
435 These dates then represent milestones that might influence the direction of the SPLWG.  
For example, collation and modeling of sediment data along with other modeling efforts  
through the Guadalupe small tributaries loading study, the break-pad partnership (Sierra  
Club, friction material manufacturers, BASMAA, and the EPA), and the CEP plus  
440 geomorphic studies on sediment processes in flood control channels might radically  
change our understanding of the distribution and loadings of sediment to the Bay. Interim  
products from the mapping task (Task 3.2) will also allow discussion and perhaps  
decisions during 2006 on how best of extrapolate data from one watershed to another  
using modeling techniques.

445 A study is presently under way (March 2005) to develop a conceptual model and  
impairment assessment for PBDEs (Oros and Werme, 2005). Funding for this study was  
provided by the CEP (Task#4.45). One of the aims of this study is to determine the  
important sources and loadings of PBDEs to the Bay. In particular, the project will  
provide comparisons of PBDE loadings from a variety of pathways including small  
450 tributaries, wastewater, and atmospheric deposition. This will provide important context  
for SPLWG activities and prioritization of future studies. The draft report is due in March  
2006 and the final report will be presented in September 2006.

ACCWP is funding a current investigation that will generate better pollutant  
455 concentration data from sediments collected from different parts of the stormwater  
system (street sweeping, inlets, depositional facilities, and de-silting projects). The last  
sampling is scheduled for October 2005 and an interpretive report will be produced in  
2006. In addition, there is a Proposition 13 study presently ongoing that is investigating  
PCB concentrations in many locations within the Ettie Street Pump-station watershed.  
460 These two studies have the potential to greatly enhance our present understanding and  
conceptual models of source-release-transport processes in urban and industrial areas and  
will likely influence SPL activities.

This section has exemplified how projects funded outside the RMP and SPLWG  
465 budgets help to influence the direction of activities and priorities. Continued or even  
enhanced coordination with other studies (discussed below in more detail) is an essential  
part of workgroup activities.

## **REVISED SPL MANAGEMENT QUESTIONS**

470 In 2003, the RMP underwent a 10-year program review (Schubel et al., 2004). In  
response to that review, the general management questions that guide the RMP were  
revised to reflect achievements to-date and the current state of our knowledge about  
priority and emerging contaminants that threaten beneficial uses of San Francisco Bay.  
The following management questions are pertinent to the SPLWG:

475 ***RMP Objective 3. Describe sources, pathways, and loadings of pollutants entering the  
Estuary***

480 3.1 *Where are/were the largest pollutant sources, in what context are/were these pollutants applied or used, and what are/were their ultimate points of release into the aquatic environment?*

485 3.2 *What are the circumstances and processes that cause the release of pollutants from both internal (Bay) and external (watershed, wetland) source areas?*

3.3 *Once released, how do pollutants travel from source areas to the Bay, what are the temporal and spatial patterns of storage, and are they transformed along the way or after deposition?*

490 3.4 *What is the annual mass of each pollutant of concern entering the Bay from each pathway?*

495 3.5 *Can data with high temporal resolution from a few watersheds be projected to other watersheds and the Basin as a whole?*

3.6 *For each pollutant of concern, what forms are released from each pathway and what are the magnitude and temporal variation of concentrations and loadings?*

500 3.7 *How do loads change over time in relation to management activities?*

3.8 *What is the relative importance of pollutant loadings from different sources and pathways, including internal inputs, in terms of beneficial use impairment?*

### **SPLWG 5-YEAR WORK PLAN (2005-2009)**

505 In October 2004, the SPLWG met to discuss the pertinent RMP SPL management questions and prioritize SPLWG activities for the next 5 years. The work group members generally agreed that unless large amounts of funding from outside the current RMP structure is successfully procured it will be impossible to address all of these management questions over a 5-year time frame. It was recognized that the SPLWG and other organizations have already generated adequate information for PCBs, Hg and other trace metal in wastewater loadings and dredge material. Atmospheric deposition is quantified for PCBs, other trace metals and Hg, but in the case of Hg, atmospheric loading makes up about one third of the estimated stormwater loading. The issue of sediment resuspension and atmospheric deposition of Hg, PBDEs, and other emerging contaminants (endocrine disruptors and pyrethroids) needs further debate by the workgroup. There remains little spatially explicit information on concentrations and loadings of priority contaminants entering the Bay from urbanized small tributaries and sediment resuspension remains a difficult input to quantify. Given that the Hg and PCB TMDL implementation recommendations ask for the measurement of loadings and trends over time-scales of 5 years and more, the measurement of tributary loadings is an agreed priority for the member agencies of the SPLWG. The SPLWG will focus on:

- Improving estimates of stormwater loadings from urban areas

525 This should be achieved through the implementation of additional small  
tributaries loadings studies (Figure 1: Recommendation D). There is a small  
amount of funding allocated in 2005 to explore potential sampling locations.  
Davis et al. (2000) recommended that six observation watersheds be picked on  
the basis of land use and climate. This recommendation remains valid  
530 however it should be recognized that stratification based on rainfall and land  
use is not mutually exclusive. Historic and current industrialized areas are  
found mainly on the lower-rainfall Bay margin. Data evaluated to help pick  
future observation watersheds will likely include the GISs of source areas and  
known use areas, existing stormwater monitoring data, storm drain sediment  
535 data, watershed size, land use, population density, the contribution of water  
and sediment from upper watershed areas, and existing USGS discharge and  
sediment data. However, the criterion for making the decision will need to be  
further discussed by the workgroup.

540 • Evaluating trends in individual watersheds

This should be achieved by implementing loadings studies over 5-10 years  
(consistent with Hg TMDL recommendations (Looker and Johnson, 2004) and  
Figure 1: Recommendation D). Given Guadalupe is likely the largest small  
545 tributary loading of Hg to the Bay Area and the fact that there is three years of  
existing data, monitoring on Guadalupe river should be continued to develop  
the first long-term dataset in the Bay Area. The Guadalupe River watershed is  
an ideal testing ground for determining trends associated with TMDL  
implementation because very large load reductions are required by the Hg  
550 TMDL. Change detection will likely require long-term datasets because inter-  
annual variability of loadings is large, however, this might be better achieved  
through the evaluation of change in particle concentrations that likely have a  
closer relationship to source characteristics than does the magnitude of annual  
loads which is strongly influenced by climate. In addition, evaluation of  
555 management actions that lead to loads avoided and the effectiveness of such  
actions should also be determined. Special studies are needed to test the  
amount of data required to observe the sediment concentration changes  
required by the TMDLs and the assist managers to decides on the best  
management methods to meet the TMDL goals.

560 • Estimating loadings entering the Bay from local small tributaries in the region as  
a whole

In the past this has been achieved by a simple area extrapolation without  
565 regard to land use, rainfall/runoff, or historic and current sources of pollution.  
Resources should be allocated to explore the use of more sophisticated models  
with calibrated and verified rainfall / runoff processes as the foundation. Such  
modeling will require continued improvement of watershed characterization  
(hydrography, rainfall distribution, imperviousness, vegetation, and land use  
570 characteristics) (Figure 1: Recommendation A). Improvements in our regional

understanding of hydrography (flow pathways and watershed boundaries) are being developed through SFEI's Proposition 13 grant. The improvement of our understanding of the influence of aspect, topography, and storm track direction on rainfall distribution is an area that might need further work.

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In addition, given that both the Hg and PCB TMDLs call for reductions of loadings from the Central Valley entering the Bay via the Delta, the SPLWG should continue to improve knowledge on the magnitude and annual variation of loadings from that pathway.

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- Measure loadings entering the Bay from the Central Valley via the Delta

This will be achieved by the continuation of the Mallard Island study on the Sacramento River near the Region 2 / Region 5 RWQCB boundary.

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Given the regional needs and priorities and the limited funding available, the following Gant Chart summarizes the presently recommended activities of the SPLWG over the next 5 years (Table 4). However, as noted above, some members support a better balance between "sources", "pathways", and "loadings" and continued work on quantification of sediment resuspension in the Bay and atmospheric deposition as a source to urban watersheds rather than a more limited focus on loadings alone. These issues require further discussion and might add to or change work plan priorities that could be reflected in subsequent annual revisions of the Gant Chart.

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### 595 **SPLWG COORDINATION WITH OTHER STUDIES (2005-2009)**

There are many important studies and programs in the Bay Area (and similar efforts in greater California and other states) that provide data, ideas, and analogies that can enhance the efforts of the SPLWG. Examples at the local level include studies by other staff at SFEI (e.g., method to monitor methylmercury in wetlands, Proposition 13 BMP assessment, NWI updates, wetland and riparian habitat rapid assessment methods (CRAM), and landscape-level wetland and stream stressor assessment methods), BASMAA, BACWA, USGS, universities, special districts, ABAG, Sustainable Conservation, SFEP, TBI, and the CEP. At the state level there are relevant projects and programs being conducted by the State Water Resources Control Board (SWRCB), other Regional Water Quality Control Boards (e.g. RB5), and CALTRANS. Notable programs in other parts of the Country include the Willamette Hg TMDL, Chesapeake Bay Programs, the Great Lakes studies, and research on environmental Hg and PCBs in the Everglades. The Sources Pathways and Loading component of the RMP can be made more successful through a plan for coordination and financial support for SPL staff to implement the plan.

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Given that the SPLWG focus at present is on loadings to the Bay, a particularly pertinent issue is the enhancement of coordination between studies on loadings and interdependent processes affecting biological targets such as bottom sediment fluxes, mercury methylation, and other food web linkages. The TMDL reports describe linkages between mass loadings and biological effects. Ongoing effort is needed to quantitatively

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**Table 4.** 5-year work plan for the Sources Pathways and Loadings Workgroup.

Activity	Funding Sources	Tools / Products	2005	2006	2007	2008	2009
*Workgroup meetings	RMP	Power Point presentations / verbal communications	\$22k	\$22k	\$22k	\$22k	\$22k
*External Coordination	RMP	Attend key meetings hosted externally, review external reports	\$0	\$7k	\$7k	\$7k	\$7k
*SPLWG expert review and meeting attendance	RMP	3 experts attend 2 meetings a year to provide independent comment	\$4k	\$4k	\$4k	\$4k	\$4k
**Development of the next 5-year plan	RMP	SPLWG meeting preparation, Written reporting					<sup>4</sup> \$15k
		Subtotal	\$28k	\$35k	\$35k	\$35k	\$50k
Mallard Island Large River Loadings Study	RMP	Empirical field data collection, Written reporting	\$51k	\$60k	<sup>1</sup> Contingency		\$120k
Guadalupe Small Tributaries Loadings Study	CEP, RMP, USACE, SCVURPPP	Empirical field data collection, Written reporting	\$50k +\$123k <sup>2</sup>	\$50k +\$77k <sup>2</sup>	?	?	?
Reconnaissance Survey of Loading Study Sites	RMP	Field observations, desktop review, Technical Memo	\$7.5k				
Additional small tributaries loadings studies	RMP 1 <sup>st</sup> year (with cost match during subsequent years?)	Empirical field data collection, Written reporting	<sup>3</sup> In-kind	<sup>4</sup> In-kind	<sup>5</sup> 150k	<sup>5</sup> 125k	<sup>5</sup> 125k
		Subtotal	\$109k	\$110k	\$150k	\$125k	\$245k
		<b>Total</b>	<b>\$137k</b>	<b>\$145k</b>	<b>\$185k</b>	<b>\$160k</b>	<b>\$295k</b>

\*Funded though normal SPLWG RMP budget (i.e. not the special and pilot studies budget)

\*\*Funded though normal SPLWG RMP budget (i.e. not the special and pilot studies budget)

<sup>1</sup>TRC provides RMP contingency funds to sample large floods as necessary - large is defined as a flood that is predicted to be larger than already observed during the period of study so far.

<sup>2</sup>Note that the total cost for WY 2005 was \$173k (\$123k match funds provided by USACE/SCVWD, SCVURPPP). The cost for WY 2006 is \$127k (\$77k match funds provided by USACE/SCVWD).

<sup>3</sup>Laboratory budget only was provided by the RWQCB for a reconnaissance study on Coyote Creek. A total of seven samples were collected during wading stage as opportunity allowed (when sampling team was able to get away from Guadalupe River study) and analyzed for Hg, PCBs, and PBDEs at the USGS gauge at HWY 237. The results will be presented to SPLWG via PowerPoint presentations.

<sup>4</sup>Laboratory budget only provided by RWQCB for a reconnaissance study on two stormwater outfalls in San Jose, sampling when opportunity allows during the Guadalupe study, analysis for Hg only.

<sup>5</sup>Not approved yet by the TRC.

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630 relate changes in mercury loadings to methyl mercury in target species (an attempt to  
integrate physical with biogeochemical processes). For example, one hypothesis might be  
that concentration and loading trends evaluated for watersheds correspond empirically to  
certain trophic transfer parameters? One might therefore examine how the proposed  
loading studies might spatially link to any RMP-supported or externally-supported  
635 monitoring of methyl mercury in water, phytoplankton, zooplankton, fish, and birds.  
Studies of methylmercury problems in tidal wetlands are developing sentinel species  
indicators that can also be used in local riverine and riparian systems. These kinds of  
linkages might require special funding consideration.

640 Funding for general coordination is handled through the “external coordination”  
component of the RMP. In 2004, SFEI SPL staff was provided with \$7,000 to complete  
this task. This was dropped in 2005 due to funding pressures. A funding level of \$7,000  
or more should be reinstated in future years (Table 4) to carry out the following activities:

- 645 • Attend meetings and read other relevant reports and products from other parts of  
the RMP, USGS, universities, CEP, BASMAA, ABAG, other RBs (RB5), and  
other States
- Review and incorporate others work into SPL reports and work products

650 In addition a further \$3,000 and travel costs (~\$1000) has been made available for  
paying for invited “experts” to attend SPLWG meetings and review SPLWG work  
products. This level of funding should be continued for the next 5 years (Table 4):

- 655 • Invite speakers to SPL to discuss new methods or pertinent recent studies
- Invite national experts to be part of the work group

## CONCLUSIONS

660 This plan has summarized the work products completed by the SPLWG over the  
past 5 years based in recommendations recorded in the “First Technical Report of the  
Sources Pathways and Loadings Work Group” (Davis et al., 1999) and refined in  
“Contaminant Loads from Stormwater to Coastal Waters in the San Francisco Bay  
region: Comparison to other pathways and recommended approach for future evaluation”  
(Davis et al., 2000). In addition, a number of other pertinent efforts (in particular the  
665 TMDL reports (Looker and Johnson, 2004; Hetzel, 2004) as well as ongoing studies have  
been summarized to provide a literature resource and overview of our current  
understanding of Sources, Pathways and Loadings of suspended sediments and  
contaminants of concern that enter the Bay annually. Taking this amassed information  
into account along with verbal feedback gained from the October 2004 and May 2005  
670 SPLWG meetings, in the context of budgetary constraints, a Gant chart was developed to  
provide guidance for SPLWG activities from 2005-2009. We anticipate the next planning  
phase will occur in 2009 but recognize that the results from SPLWG studies and studies

by other groups in the Bay Area and nationally may cause modification of this work plan during this 5-year period.

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