MASS EMISSIONS REDUCTION STRATEGY FOR SELENIUM

Supplemental Staff Report

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I. INTRODUCTION

This document clarifies and describes changes made to the proposed Mass Emission Reduction Strategy for selenium (MERS)[1] in response to public review. It is intended as a supplement to the published supporting staff documents and previous annoucements. Detailed responses to written comments are contained in Appendix A.

II. REGULATORY CONTEXT

During public review of the proposed selenium MERS, several entities expressed concern over whether the MERS is in accordance with the Clean Water Act and EPA guidance on implementing the requirements of federal law, Porter Cologne, CEQA, and state policy as laid out in the Pollutant Policy Document. This section clarifies issues **not** described in the original staff report.

Clean Water Act

Three issues with respect to the Clean Water Act (CWA) and were raised during public review: whether the MERS violated CWA requirements that emissions reductions take place within three years of listing a waterbody as impaired under 304(l), the degree to which the MERS was in accordance with EPA's guidance on TMDL development, and development of the ecological assessment guidelines in accordance with EPA guidance on developing water quality criteria.

First, the MERS is independent of the 304(l) listing and loading reductions the refineries are currently required to make by December 1993. The proposed refinery reduction schedule in the MERS does not begin until after the December 1993 deadline stipulated in 304(l)-related reductions and assumes that required loading reductions will be achieved. In response to concerns regarding the possibility of further water quality degradation between the December 1993 304(l) deadline and the initiation of further reductions according to the MERS in 1995, the starting date for the MERS has been moved up to January 1, 1994.

The MERS was developed, where possible, in accordance with all EPA policies. Specifically, the guidance for developing water quality criteria and wasteload allocations under the phased TMDL process were adhered to. The only exception is where EPA policy was specifically designed to limit effects of toxics in the water column and did not provide for compounds that primarily affect ecological systems

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[1]. The following discussion is based on the text of a proposed Basin Plan amendment (public hearing held January 20, 1993), the supporting staff document (published October, 1993), and written and oral comments received by January 31, 1993. This document serves as an addendum to the October staff report.

through the food chain.

Porter Cologne and CEQA

The specific language of the Porter Cologne Act raised in public review related to the water quality conditions that could reasonably be achieved through coordinated control of all factors which affect water quality in the area and economic considerations. The process of developing and implementing the MERS follows these requirements of Porter Cologne in several ways. The first step in assessing control of all factors was to determine the amount of loading from each source based on current information. These data indicate controls on refinery discharges into the North Bay would likely have a significant impact on levels of selenium in the aquatic system. Source data for the South Bay is not complete enough at this time to indicate the most significant sources of selenium loading, thus no judgement has yet been made regarding what sources could reasonably be controlled. Economic factors have been implicitly considered at many steps in this process. First, only the most significant sources have been targeted for immediate reductions. Additional information is being gathered to assess loadings from more diffuse and much less concentrated sources--both factors usually increase the cost or complexity of treatment. Second, the cost of gathering information, in addition to the cost of developing treatment, has also been implicitly considered in the MERS. When the costs of achieving a much higher level of certainty (in, for example, obtaining a Bay-species specific NOAEL for organic selenium) in the predictive model appear to far outweigh the cost of developing control technologies, the MERS emphasizes investing in technological design over further research. Finally, the present state of knowledge does not allow for a prediction of food chain levels that would result under different reduction scenarios. To address this, the MERS specifically allows for monitoring the effects of significant loading reductions in the northern part of the Estuary. In summary, the MERS was both designed to comply with and present a policy process that complies with Porter-Cologne.

There were three issues regarding the CEQA checklist generally raised in public review: whether the MERS would significantly affect existing energy sources, has the potential to achieve short-term to the disadvantage of the long-term environmental goal of hazardous waste reduction, and whether there was an evaluation of the feasibility of alternative mechanisms for controlling selenium loading.

As the most promising option for reducing mass emissions from the refineries in the shortest period is an effective control strategy, the revised MERS is no longer likely to significantly affect crude oil supply.

The environmental impacts of hazardous waste are related to how people and ecoystems are exposed to such material. At this point in time, selenium waste is

currently being discharged into the Bay, thereby exposing the entire aquatic ecosystem to elevated levels of selenium. To accurately judge whether the MERS would achieve a short-term goal of reducing selenium emissions into the Bay at the expense of a long-term goal of reducing hazardous waste generated by emission control processes would require a comparative assessment of the environmental risks associated with air, water, or land disposal of the selenium waste. At this point in time, it appears that properly stabilized, solid waste woul, by far, pose the least long-term environmental risk.

The feasibility of alternative mechanisms for controlling selenium loading is actively being addressed in three ways. First, the development of effective refinery controls will be continuously monitored and reviewed through the establishment of a task force (see description of activities below). Staff have already begun such reviews and concluded, for example, that significant changes in the types of crude oil processed by Bay Area refineries would not achieve a significant percentage of target emission reductions and would likely require more time than developing technological controls. Second, investigations into the precise source of selenium loading from POTWs are planned. Such investigations would determine, for example, whether it is more feasible to control loadings from POTWs by end-of-the-pipe treatment or controls on selenium entering the water supply. Third, more precisely quantifying contributions from riverine and runoff, as proposed in the MERS, will better define how coordinated control of all factors would best be achieved. These review processes will, in effect, provide the review of technological alternatives as required by CEQA.

III. IMPLEMENTATION OF THE PROPOSED MASS EMISSION REDUCTION STRATEGY

Many issues with respect to the implementation of the MERS were brought up in the course of public review. The following discussion is broken down into subject areas most frequently commented upon.

Water Body Segments

There are two different concerns with respect to selenium levels in the Bay water and food chain: widespread geographic areas where selenium levels are generally much higher than other areas of the Bay and/or selenium-normal aquatic systems, and isolated areas of elevated food chain concentrations. Segments of the northern reaches of the Estuary, specifically San Pablo Bay, Carquinez Strait, and Suisun Bay, are areas where there appears to be widespread food chain enrichment. Selenium levels in the Central and South Bays indicate much more localized enrichment. Bivalve data (Appendix B) in particular indicate tissue concentrations in most of the South and Central Bays are at background levels, with the exception of a few sampling sites. The eastern shore of the South Bay, however, has not been as extensively studied. Because selenium levels are not as consistently high in the South

Bay it is premature to establish specific geographic limits for the purposes of deriving loading reductions until more information is available on the relationship of localized sources and observed food chain enrichment. Loading to the South and Central Bays, then will be capped at current levels.

Refinery Emissions and Reductions

Several changes to the proposed MERS with respect to refinery emissions have been made, specifically an analysis of the potential for crude management to significantly reduce current loadings and changes in the dates of the timeline for loading reductions.

1. Alternative Control Strategies: Crude Management

The strategy of controlling selenium emissions by altering the type of crude oil processed by Bay Area refineries was proposed by local environmental groups. Board staff requested information from the refineries in fall of 1993 in part to evaluate the potential for crude management to reduce selenium loading. Although almost all of the selenium entering refineries does so through the crude, available information indicates a) selenium content of crude is variable, b) the type of refining process affects the amount of selenium in the effluent, c) in addition to the variability of crude selenium content, there may be multiple internal sources, sinks, and unquantified volatilization of selenium compounds--the result of which is that selenium in the effluent can not be accurately predicted from crude selenium levels, and d) if all high-selenium crude refined in the Bay Area were substituted with lower selenium crude, the maximum loading reductions likely to be achieved under ideal conditions is less than 50% of 1992 emissions; such reductions would probably take more time to implement than the proposed control technologies and have significant economic repercussions. Based on this information, it appears that the best alternative for achieving significant emissions reductions in the shortest amount of time is the development of control technologies. Work currently being undertaken in the process of designing such measures could, however, result in a much clearer understanding of the relationship between crude selenium levels, specific processes, and overall selenium emissions.

2. Selenium Emission Data

Data from refinery loadings were updated to include actual 1992 loadings and emissions reported for 1986-198. Values differ slightly from Table 6 in Oct. 12 staff report. The former were calculated for 1989-1992 by multiplying the concentration at each sample data by the cumulative flow between sample dates. Values presented in Table 1 were calculated from rolling annual loading averages (sample concentration

times flow on that date, averaged over a year of monitoring). The calculation method was changed to be consistent with the method currently used in refinery permits.

Table 1. Annual Refinery Selenium Loads (kg/yr) into San Francisco Bay

	1986	1987	1988	1989	1990	1991	1992	Average Load
Shell	803	694	767	547	822	946	1178	822
Unocal	694	475	584	657	881	876	768	705
Chevron	767	365	292	256	311	262	161	345
Exxon	146	292	219	219	272	363	343	265
Tosco	219	183	146	111	82	108	88	134
Pacific	–	–	–	7	6	6	4	6
TOTAL	2629	2009	2008	1797	2374	2561	2542	2277

Table Notes:
Values presented in this table differ slightly from values presented in the October staff report because the former calculated loading assuming emissions equivalent to concentration and flow on sample date during the whole period between sample dates. The loading figures in this table assume annual emissions are equivalent to the annual average daily load multiplied by 365 days.

3. Timetable for Emission Reductions

In response to several comments regarding the starting date of the proposed MERS and the need for a longer period of review after a 75% reduction had been achieved, the proposed emission reduction schedule was changed (Table 2).

In some cases, attainment of the target loading reductions may not be technologically feasible. At the same time, development of such technologies must be expedited. Such a situation may be addressed by having an advisory task force assist Board staff determine whether, for example, dischargers have made a good faith effort to design and/or install treatment technologies, or whether a substantial environmental benefit may be gained by further modifications in control technology design. Prearranged agreements on penalties for not meeting the scheduled reductions would be encouraged.

Table 2. Proposed Emission Reductions and Schedule

Year (Jan-Dec)	Total Amount of Permitted Se Loading (kg/yr)	Cumulative Reduction From Baseline[a]
1993	1212[b]	46%
1994	1010	55%
1995	785[c]	65%
1996	561[d]	75%
1997	561[e]	75%
1998	561[e]	75%
1999	561[e]	75%
2000	337	85%
2001	224[f]	90%

Notes:
Values differ slightly from the October staff report because the former calculated loading assuming emissions equivalent to concentration and flow on sample date as representative of the period between samples. These loading figures are instead based on an assumption that annual emissions are equivalent to the annual average daily load multiplied by 365 days.

a Baseline was defined as the average annual loading during '89-'91 (2244 kg/yr).
b Emission levels required by current NPDES permits.
c Refinery loading equal to average riverine loading
d Preliminary goal discussed as target for control technologies.
e Review of ecological monitoring data to determine in further emissions reductions are necessary.
f Refinery loading comparable to riverine loading during periods of low flow.

Task Forces

After the public hearing on the proposed MERS, the establishment of two advisory task forces was proposed--one to oversee the development of control technologies by the refineries, and the other to oversee and discuss issues related to monitoring and assessing selenium levels in the Bay water and food chain. The general purpose of each task force is to assure public input in critical decision making areas and assist in the development of policy with respect to complex technological and scientific issues.

Persons affiliated with environmental groups and the oil refineries were initially

The specific charges of the technological task force are to address issues such as:

- the adequacy of efforts made by refineries to develop and implement control technologies

- the likely impact of upcoming refinery process changes made to accommodate the new clean fuels

- the feasibility of installing package plants between the time an effective control process is discovered and full scale implementation

- under what conditions extension of research time to reduce amount of waste produced by control processes should be granted

- whether penalties are appropriate if loading reductions can not be achieved according to the reduction schedule, and if so, what factors should be considered in assessment of these penalities

The specific goals of the technological task force will be determined by participants.

POTW and Non-Point Loading

There are two main clarifications with respect to the proposed strategy for assessing and deriving mass loading limits for POTWs and non-point sources. First, the proposed submission of effluent monitoring data reflecting lower analytical detection limits for selenium was only intended to apply to those dischargers not regularly detecting selenium at this time. Dischargers reporting detectable concentrations need not seek more accurate analyses. Second, the goal is to detect selenium, not to use excessively precise monitoring. For example, if less sensitive techniques demonstrate selenium levels are between 0.5 and 1.0 ug/l, it is not necessary to use analytical methods capable of detecting as little as 0.01 ug/l.

Permit Limits/ Enforcement

There were several questions about the enforceability of the mass limits proposed in the MERS. Mass limits would be described and enforced as they are in current permits. Specifically, caps on loading from specific discharges would be defined, monitored in accordance with current permit requirements, and calculated

from concentration and flow data. Adherence to the permit limit would be evaluated based on a rolling annual average of mass loading.

The MERS calls for caps on all current mass loading of selenium to the Bay, a specific timeline for reductions from known major sources, and an assessment of other potentially major sources and associated reductions.

III. ECOLOGICAL ASSESSMENT GUIDELINES

The ecological assessment guidelines presented in the staff report were derived from a thorough review of existing scientific literature on the subject and as such, are knowledge-based. They are a means of interpreting the narrative water quality objective and will be reviewed and updated as more information on selenium biogeochemical cycling in the Bay becomes available. Most commentors discussed the guidelines as if they were predictive models resulting from intense, long-term, scientific studies of selenium in the Bay. Issues about the interpretation of future monitoring data, acceptable levels of certainty, and tradeoffs between accuracy of the food chain model and accuracy of monitoring data will be discussed and incorporated as refinements in the proposed MERS. A second task force to oversee monitoring efforts and interpretation will be convened as a mechanism for resolving these issues during the implementation of the MERS. In addition, this task force will assist in scheduled reviews of the assessment guidelines to assure new information is taken into account.

Review of the guidelines has demonstrated that the highest research priority os to qualitatively and quantitatively assess the uptake of selenium by primary producers in the Estuarine ecosystem.

Based on revisions in the NOAELs and biomagnification factors described above, several changes have been made in the ecological assessment guidelines.

No Observed Adverse Effect Levels

Summary of Changes:

- NOAEL for mallards was changed from 4 to 4.5 in response to comments regarding moisture content of feed.

- NOAEL for chinook parr-smolt transformation was changed from 6.5 to 8.8 ug Se/ g feed dw in response to comments regarding moisture content of feed. The value was calculated on the basis of feed composition of 84% Oregon Moist Pellets (30.7% water, 0.5 ug Se/ g wet pellet) and 16% freeze-dried mosquitofish

(38 ug Se/ g dw).

• Additional information added to the NOAEL for chinook in response to comments.

For more discussions of these and responses to comments, see Appendix A.

Biomagnification

In response to comments and further review of data on selenium in marine food chains, the biomagnification factor has been changed from the range from 2-6 to 2-10 to better reflect marine rather than freshwater food chain levels.

Liu et al. (1987) analyzed selenium levels in many different marine organisms. They concluded that while selenium levels in muscle tissue tend to increase slightly along trophic levels, Se:C ratios were roughly the same--indicating that tissue burdens at higher trophic levels are the result of very efficient food chain transfer and not biomagnification. In analyzing the degree of Se accumulation, these researchers analyzed tissue levels in a) a benthic food chain, b) different trophic levels of bottom fish, c) different trophic levels of surface fish, and d) different trophic levels of mid-water fish. In the benthic food chain, comprised of intertidal macroalgae, herbivorous gastropods, omnivorous crustaceans, and carnivorous anthozoa, selenium increased 10 fold between the first and second trophic level, and 21-fold between the first and third trophic level.[2] In the other trophic studies, selenium increased ~2 times from the second to third trophic level of bottom fish[3], mid-water fish, and surface fish. These data suggest different effective biomagnification factors depending on food chain and plant species.

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[2]. Because the benthic pathway is likely to be more important in the Bay than in the coastal waters sampled by Liu et al. (1987), the higher biomagnification factors for that pathway must be taken into account (the 10-fold increase between the first and second trophic level is most appropriate for limiting levels in bivalves consumed by ducks).

[3]. All calculations made with respect to muscle tissue.

Table 3. Summary of LOAELs and NOAELs of Se in Feed

LOAEL in feed*	NOAEL in feed*	Se form	Effect	Organism	Source
8	4.5 (est)	Se-meth	duckling survival	mallard	Heinz *et al.*, 1990
	4.5	Se-meth	[using same data as above]		Peterson and Nebeker, 1992
	8.8	Se-meth	parr-smolt transition	chinook	Hamilton *et al.*, 1986
	5	inorg. and org.	growth	mammals	Peterson and Nebeker, 1992
18.2	9.6	Se-meth	growth (fingerlings--brackish water, 120d)		Hamilton *et al.*, 1990
9.6	5.3	Se-meth	growth (fry--freshwater, 60d)	chinook	Hamilton *et al.*, 1990

Table Notes:
* All values in ug/g as Se, dry weight

Water Column Limit

The changes in the NOAELs and biomagnification factors summarized above also change Equation (2) of the staff report to:

$$\text{Water column limit (ug/kg)} = \frac{\text{4.5-9.6 ug Se/ g dw x 1000 g/kg}}{\text{2-10 x BCF (algae)}}$$

Equation (2)

$$\text{Water column limit (ug/kg)} = \frac{\text{0.45-4.8 ug Se/ g dw x 1000 g/kg}}{\text{BCF (algae)}}$$

The October staff report described two methods of calculating a BCF for selenium and primary producers. The two options were to use reported literature

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values for a BCF or to use a model relating selenite levels in the Bay water to selenium in total suspended material. There is not enough information available at the current time to use either method of calculating an algal BCF. Understanding the rate and pathways by which selenium enters the Bay food chain is the highest research priority. The TSM: selenite model will, however, be used in any review of particulate- and sediment-bound selenium biogeochemical cycling pathways. Discussions about many different aspects of the model, including linear vs. hyperbolic curve fitting, extrapolations beyond data set, selenite:selenate ratios, etc. are contained in responses to comments in Appendix A.

Total Suspended Material and Algae and other aquatic plants

Two changes have been made to these guidelines. First, the assessment guidelines are given as ug organic Se/ g dw instead of ug total Se/ g dw. Second, the value has been recalculated based on changes in the NOAELs and biomagnification factors described above from 0.7 ug/g dw to 0.45 ug organic Se/ g dw.

Normalizing the measurement of selenium to the amount of organic selenium contained in either aquatic plants or totals suspended material reflects two concerns: the NOAELs are derived on the basis of organic selenium species (not inorganic species) and comparability of data on the selenium content of different species from different aquatic systems. While this definition makes the guidelines more consistent with the selenium biogeochemical cycling model presented in the staff report, it is unclear to what extent analytical methods are available to produce such data. The apparent trade-off between greater accuracy in the model/ less accuracy in monitoring and greater accuracy in monitoring/ less accuracy in the guidelines should be the subject of discussion by a committee establishing more precise protocols for ecological monitoring and evaluation.

Bivalves

Additional bivalve data and comments on the staff report have been reviewed. The assessment guideline has been changed from 3 ug/g dw to an elevated data level (EDL) of 3.2 ug/g dw, and alert level of 4.5 ug/g dw (from the NOAEL data). The guideline was not changed from total selenium in tissue to organic selenium in tissue because a large fraction of selenium found in marine animals is already in the organic form (60-99%; Phillips, 1988) and because none of the extensive monitoring data available distinguishes between inorganic and organic Se in bivalves. The distribution of tissue levels (only those reported as dry weight) for mussels and *Corbicula* sp. are presented graphically below. All bivalve data used in the review can be found in Appendix B.

Sampling data taken from State Mussel Watch coastal reference sites show a skewed distribution of selenium levels, with a mean of 2.5 ug/g dw and a maximum of 3.2 ug/g dw. This is the basis for the EDL of 3.2 ug/g dw.

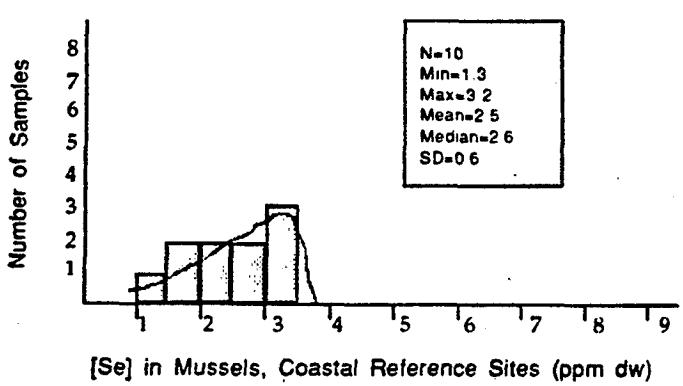
Mussel data from the South Bay indicate that there is no widespread exceedance of the EDL, but a few locations where either the EDL or both the EDL and alert level are exceeded. Further investigations of selenium levels in the food chain and potential sources should focus in on these areas. Data from the North Bay show a more even distribution, with roughly the same fraction of samples exceeding the EDL and alert levels, but fewer extremely high tissue levels. A different species of bivalve was used in the Carquinez Strait and Suisun Bay area, so direct comparison with background levels from coastal reference sites is impossible (once located, reference data for *Corbicula* will be used). However, the mean tissue level is much higher, exceeding the 4.5 ug/g alert level.

An EDL for Rallid eggs of 2.9 ug/g dw based on data from USFWS indicating eggs from Se-normal environments contain between 0.4 to 2.9 ug Se/ g dw. A LOAEL for selenium in eggs of 3.9 ug Se/ g dw based on observations of imparied immune function of hatchlings was also suggested (See Appendix A). After further review of this literature, an NOAEL for selenium in fowl eggs will also be developed.

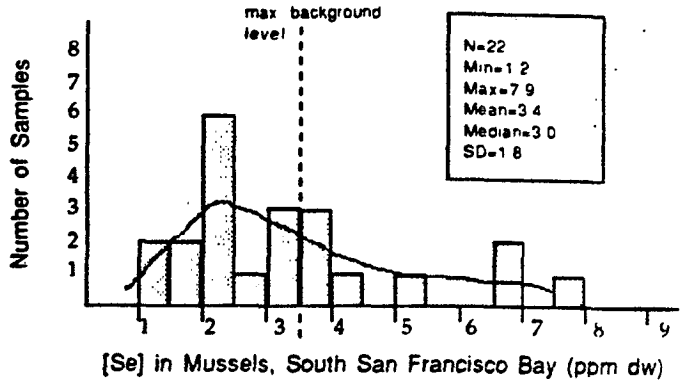
Table 4. Summary of Ecological Assessment Guidelines

Organism Type/ Compartment	Guideline
Water	Pending new information on uptake of Se by primary producers
Total Suspended Material (> 0.45 um)	0.7 ug organic Se / g dw
Algae and other aquatic plants	0.7 ug organic Se / g dw
Sediment	1.5 ug/g dw
Bivalves	EDL: 3.2 ug/g dw; 4.5 ug/g dw
Rallid eggs	EDL: 2.9 ug/g dw

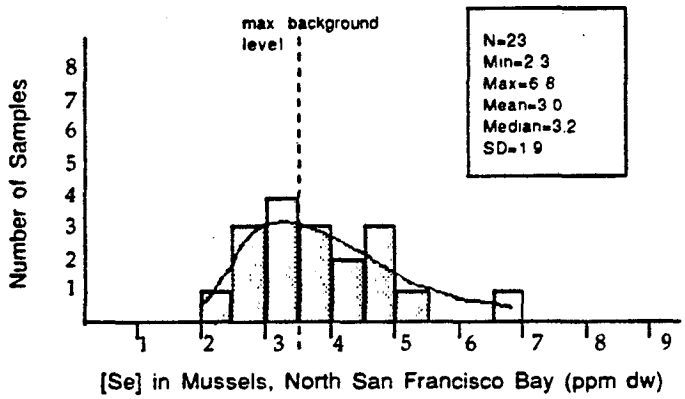
Figure 1. Frequency of Se Levels Found in Bay Bivalves



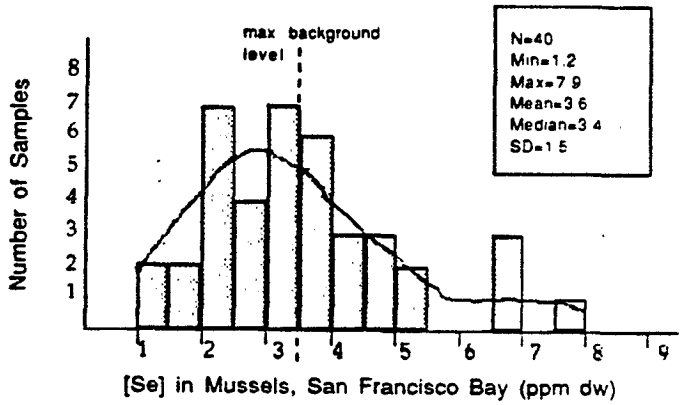
[Se] in Mussels, Coastal Reference Sites (ppm dw)



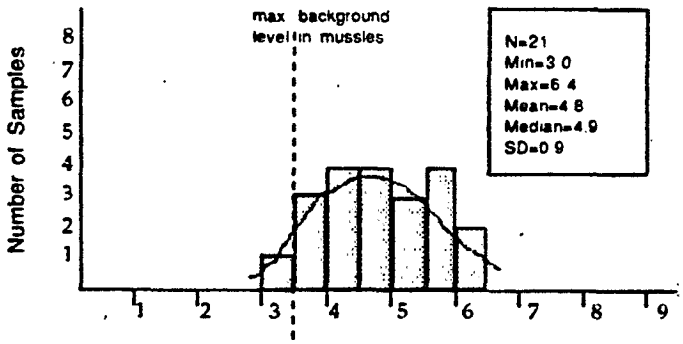
[Se] in Mussels, South San Francisco Bay (ppm dw)



[Se] in Mussels, North San Francisco Bay (ppm dw)



[Se] in Mussels, San Francisco Bay (ppm dw)



[Se] in *Corbicula*, Carquinez Strait and Suisin Bay (ppm dw)

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APPENDIX A: Responses to Comments Received on the Proposed Mass Emission Reduction Strategy (MERS) for Selenium

Summary of Correspondence Received

Organization	Author	Client	Date of letter
City and County of San Francisco	James Salerno		Oct. 27, 1992
Citizens for a Better Environment	Greg Karras		Nov. 5, 1992
Santa Clara Valley Water District	Roger James		Nov. 4, 1992
Adams and Broadwell	Marc Joseph	N.CA and N.NV Pipe Trades Council # 51	Nov. 6, 1992
Santa Clara Valley Audubon Society	Trish Mulvey		Nov. 9, 1992
City of Palo Alto	Phil Bobel		Nov. 10, 1992
The Bay Institute	Gary Bobker		Nov. 10, 1992
State Water Resources Control Board	Jesse Diaz		Nov. 13, 1992
Western States Petroleum Association (WSPA)	Scott Folwarkow		Nov. 13, 1992
Shell Oil	J.C. Harmon		Nov. 13, 1992
California Energy Commission	B.B. Blevins		Nov. 18, 1992
Environmental Defense Fund	Terry Young		Nov. 18, 1992
City of San Jose	Kent Dewell		Dec. 2, 1992
Exxon	Todd Royer		Dec. 10, 1992
USFWS	Wayne White, Joe Skorupa		Dec. 17, 1992
CA Dept. of Conservation	Edward Heidig		Dec. 23, 1992
WSPA	Scott Folwarkow		Jan. 20, 1993
Exxon Biomedical Sciences (comments on staff report)	Ray Arnold		Jan. 20, 1993
Exxon (information on Se nutritional requirements)	Ray Arnold		Jan. 20, 1993

Eisenberg, Oliveri & Associates	Adam Oliveri	City of Sunnyvale	Jan. 25, 1993

Comment: The contribution of sewage treatment plants to the total selenium loading into the Estuary is overstated because relatively high detection limits were used to calculate mass loadings. Loading estimates for San Francisco should be adjusted to reflect much lower detection limits currently in use (San Francisco).

Response: Agree. Mass loading levels from POTWs are constantly being updated as new information becomes available.

Comment: The proposed MERS gives oil refineries a ten-year extension over the existing December 1993 deadline to reduce mass emissions (CBE).

Response: The timetable for mass emission reductions from the oil refineries assumes that decreases required by December of 1993 will be achieved prior to the first year of the MERS. Thus, the proposal is a strategy to reduce emissions beyond the 1993 limit and is independent of the earlier requirements.

Comment: Violations of the December 1993 mass emission limits should be assessed on a case-by-case-basis where the assessment includes a consideration of penalties and means of remedying violations (CBE).

Response: This is in accordance with standard operating procedure.

Comment: Feasibility of reducing selenium emissions has not been adequately investigated by the refineries or the Board (CBE).

Response: There has been considerable effort by Board staff to obtain and evaluate all available information on selenium at each refinery. Considerable effort has also been made by the refineries to unravel the technical difficulties surrounding even basic questions such as what form of selenium is in process streams throughout the refineries? The comment, however, points to a key issue--the meaning of "adequate" investigations. We have proposed the formulation of a task force to address this and other issues relevant to control methods.

Comment: A numeric water quality objective for selenium should be established, specifically at 0.06 ug/l. This value is justified on the grounds that selenium flow and conversion through sediment pathways was not considered in the derivation of the water column assessment guideline (CBE).

Response: A water quality objective represents a concentration which, if maintained, would prevent adverse impacts on beneficial uses. As much information about the uptake of selenium from water by aquatic plant species in the Bay is unavailable, no water column objective can be calculated at this time.

According to EPA guidelines on developing a phased TMDL, the worst possible case scenario is to be assumed and safety factors used to account for uncertainty. All values presented in the MERS staff report were derived according to these guidelines by using the most conservative values when choices were necessary in calculations instead of using safety factors at the end of the derivation process. At this point in time, it is impossible to qualitatively or quantitatively assess the significance of the sediment pathway. As new scientific information becomes available, it will be reviewed, the conceptual model adjusted if necessary, and a water column objective proposed when there are sufficient data to support it.

Comment: The lack of a numeric criterion allows sewage treatment plants to continue discharges without concentration or mass limits that require reductions from current discharge levels (CBE).

Response: Sewage treatment plants are operating under discharge limits and the vast majority of them are reporting levels of selenium below detection limit. The MERS proposes capping discharge at current levels pending a thorough investigation of actual loading from these and other potential sources (such as water supply), particularly in the South Bay. Once sufficient information has been gathered, it will be evaluated to determine the degree to which mass loading from these sources should be reduced.

Comment: Limit the total mass loading of selenium into Carquinez Strait, Suisun, San Pablo, and Central San Francisco Bay to 216 kg/yr. This loading limit is justified because the Clean Water Act requires using a margin of safety (CBE).

Response: The proposed MERS follows the phased TMDL development process as described in EPA's guidance documents. The phased development process necessarily involves an iterative process of reducing emissions by feasible control methods and further ecological monitoring to evaluate both food chain levels and the effects of required reductions. Loading reductions less than those proposed in the comment letter may have the desired effect. As discussed above, a margin of safety has been consistently used in the derivation of the assessment guidelines.

Comment: The allowable mass loading should be allocated among individual permit holders. Permit limits should be water quality-based unless it can be shown that higher mass emissions a) preserve beneficial uses and b) the total maximum load can be attained by loading reductions elsewhere (CBE).

Response: Our understanding of the term water quality-based is that it distinguishes regulatory programs (mandated by the Clean Water Act) based on the ecological state of an actual waterbody from programs based on having dischargers install modern, available treatment technology (best available technology). The MERS was designed entirely under the water quality-based system.

Mass emissions are currently allocated among individual permit holders by virtue of the limits in current permits. Allocation of reductions between dischargers beyond those already written into individual permits is an issue which needs to be resolved and may be best addressed when technological controls are implemented.

It is not clear what "higher" mass emissions refers to--the proposed MERS calls for overall reductions that would likely only be achieved if all sources significantly reduced mass loading. Any emissions trading, then, would only affect which area was cleaned up first, not where loading levels were likely to increase.

Comment: A limit on selenium discharge from all refineries is less enforceable than limits in individual discharge permits (CBE).

Response: Mass loading limits will be included in individual permits. The limit for selenium discharge from all refineries will be established in the Basin Plan. Limits for individual dischargers will be developed subsequently.

Comment: The MERS violates section 304(l) of the Clean Water Act which requires clean-up measures as soon as possible (CBE).

Response: The MERS is completely independent of the emission reduction deadline set under the 304(l) process and is designed to force the development of effective control strategies on a timely basis.

Comment: Setting reduction targets as percentages of recent instead of older emissions will result in a)

higher loading levels after initial reductions have occurred and b) unfairly reward dischargers who have recently increased their emissions or currently use high detection limits (CBE).

Response: The baseline years for oil refinery reductions were chosen to be consistent with previous actions. State policy requires emissions from the three most recent years to be used in calculating baseline emissions for mass reduction plans. The goal of the MERS for dischargers other than the refineries and non-point sources is to more accurately describe loading, rather than set up requirements to "reduce" emissions by lowering detection limits.

Comment: Staff report does not analyze how different refinery processing and control measures could reduce selenium loading (CBE).

Response: Staff have and will continue to request that such studies be done by permitted discharges. To help evaluate the information, we are convening a task force to ensure public input.

Comment: It would be very difficult to reduce effluent concentrations of POTWs below current discharge limit of 2 ug/l through treatment. Any reduction strategies should focus on reclamation and source control (Santa Clara).

Response: The current goal of the MERS is to better identify sources of selenium loading from and to POTWs before even considering control options.

Comment: Using water reclamation to reduce mass loadings to the Bay may result in high levels in soil which, in turn, may enter the Bay in non-point runoff (Santa Clara).

Response: Noted.

Comment: Water suppliers are currently initiating a monitoring plan to determine amount of selenium in water supply. Suppliers who draw from the Delta have little control over selenium levels there. Thus, loading reductions from some POTWs may be best achieved by limiting selenium loading from agricultural sources in the San Joaquin (Santa Clara).

Response: These issues will certainly be evaluated as the information becomes available to do so.

Comment: The target detection limit of 0.01 ug/l can only be achieved by two laboratories in the country. Requiring routine monitoring at this level would be a substantial burden and is not adequately justified by the staff report (Santa Clara).

Response: The target detection limit was proposed as a temporary measure to obtain more accurate data on loading from POTWs. Those dischargers currently detecting selenium in their effluent need not use more sensitive analytical techniques. The target of 0.01 ug/l was proposed because it is the same order of magnitude as Se levels in relatively uncontaminated areas of the Estuary and is less stringent than requiring a more sensitive method used by Cutter. Finally, as these monitoring data will be used to assess the need for and eventually allocate mass loading limits, it is reasonable to require more precise information to a) ensure no increases in selenium loading actually occur and b) to only require reductions from the most significant sources in the first phase of the MERS.

Comment: Refinery discharge limits currently required under section 304(l) (reduction to 1212 kg/yr by Dec. 1993) are not stringent enough to satisfy the requirements of the Clean Water Act (Adams and Broadwell).

Response: Noted. As discussed above, the MERS is independent of the 304(l) listing. Comments specifically addressed to the 304(l) listing, subsequent reduction requirements, and enforcement will not be discussed here as the matter is currently under litigation.

Comment: The proposed reduction schedule should be accelerated, and begin in 1993 instead of 1995. There is no reason why reductions should be delayed until a wastewater treatment technology is brought on line. In the short term, the proportion of high selenium crude oil refined should be reduced and package plants be installed on wastewater streams which are the source of selenium (Adams and Broadwell).

Response: It is unlikely that significant changes in the crude oil slate of the refineries using high selenium crude can be changed in a short time frame (other than marginal changes probably on the order of less than 10%). It is unclear even what rough methods of removing selenium would form the basis for the proposed package plants. When pilot-level removal methods exist, the package plant option should be considered. The timeframe for refinery reductions has been changed to begin in 1993.

Comment: Top priority should be given to achieving maximum refinery load reductions as soon as possible. Support coupling the phased loading reduction (with eventual reduction of 90%) with biomonitoring (Adams and Broadwell).

Response: Noted.

Comment: The MERS should begin in 1993, not 1995 (Audubon Society).

Response: The timetable for refinery reductions has been changed to begin in 1993.

Comment: Compliance with loading reductions already required of the refineries should be enforced (Audubon Society).

Response: Board staff are working on enforcement of interim limits.

Comment: Consideration should be given to alternate sources of crude, alternate product mixes and productions processes, and alternative treatment options for selected waste streams as means to immediately reduce selenium loading (Audubon Society).

Response: It is unlikely that significant changes in crude oil slates can be accomplished any faster than development of effective control technologies. Information provided to Board staff by the refineries also indicate it is currently impossible to predict the extent of selenium emission reduction even from the total amount entering the plant in the crude. Consequently, it is unclear exactly which processes, products, etc. might be changed, by how much, and the degree to which emissions could be reduced by such measures. Work is currently being planned by WSPA to develop adequate testing measures for selenium. When such protocols have been developed, an understanding of selenium flow through various refinery operations can be used to better assess the potential for modifications to achieve loading reductions.

Alternative treatment options for different waste streams are being actively considered by a WSPA technological study group.

Monitoring the development of treatment options and development of information on selenium flow through the refineries is the primary purpose of the task force we are convening.

Comment: A water quality standard less than 1 ug/l should be adopted and a wasteload allocation developed for the South Bay. Effluent limits in permits should be adjusted accordingly (Audubon

Society).

Response: The MERS includes the development of a wasteload allocation for the South Bay once more precise loading data are available. Some South Bay dischargers are currently operating under 2 ug/l effluent limits; we also believe selenium levels in municipal discharges throughout the Bay to be generally much less than 1 ug/l. Thus, almost all POTWs would already be in compliance with a water quality objective near 1 ug/l.

Comment: There is no evidence of significant local runoff sources of selenium. Priority should thus be given to refinery and POTW wasteload reductions (Audubon Society).

Response: There is one stream in the extreme South Bay where relatively high levels of selenium have been detected. The MERS targets the most significant sources of selenium for loading reduction in the first phase.

Comment: A short-term, specialized sampling program should be used, if necessary, to determine potential loading from stormwater runoff. Such monitoring should be compatible with the South Bay water characterization project now being planned and pay particular attention to drinking water wells in the Santa Clara Valley and water supplied from the San Joaquin (Audubon Society).

Response: Agree.

Comment: It should be made clear that the recommendation of using lower detection limits for POTW discharge should only apply if current effluent monitoring does not detect selenium (Palo Alto).

Response: Agree. Our intent was to request those dischargers consistently reporting non-detects to use more sensitive methods. See above discussion.

Comment: A coordinated (rather than individual) assessment of selenium sources to POTWs and the feasibility of reducing mass loads should be conducted before target reductions for POTWs calculated (Palo Alto).

Response: Noted.

Comment: New water quality objectives which guard against bioaccumulation should be developed before any waste load allocation. Allocations not based on water quality objectives would be arbitrary (Palo Alto).

Response: The MERS follows EPA guidelines for the phased TMDL process, using the narrative standards as a basis for determining ultimate loading limits. Wasteload allocations will take into account all available knowledge on food chain levels and selenium sources, rather than being solely derived on the basis of effluent and receiving water column concentrations.

Comment: Instituting a biomonitoring program and reducing mass loading of selenium into the Estuary by 90% is the most effective way to achieve protection of beneficial uses (Bay Institute).

Response: Noted.

Comment: The proposed time frame for accomplishing the mass loading reductions is too long and represents an extension of the time by which refineries are currently required to reduce their emissions to 1995 (Bay Institute).

Response: As discussed above, the MERS is completely independent of the December 1993 deadline and assumes the required loading reductions will be achieved before the MERS begins. Comment on length of proposed time line is noted.

Comment: Burden of proof lies with the refineries to demonstrate inability to comply with the current and proposed deadlines. If the case can be made for the inability to comply, exemption from targeted dates should be granted on a case-by-case basis (Bay Institute).

Response:One of the issues for the task force will be to determine appropriate criteria and conditions for allowing extensions to the target dates.

Comment: There should be an unequivocal commitment to a 90% mass emissions reduction because of contributions from non-refinery sources (Bay Institute).

Response: The targets of 75% and 90% emissions reductions apply only to the refineries. Reductions from other sources such as riverine input will also be assessed more information becomes available.

Comment: Site-specific criteria may be necessary to prevent further degradation of beneficial uses in "hot spot" areas. Consideration should be given as to whether numeric criteria for effluent would best achieve this goal (Bay Institute).

Response: Implementation of the proposed MERS would involve numerical mass loading limits in the individual permits and loading decreases from the most significant sources. It is unclear from the comment how the process of developing and using numeric criteria differs from the MERS.

Comment: The San Joaquin Valley Drainage Program concluded 0.5 ug/g of selenium in sediments is an indicator of possible contamination. A standard for detritus (as different from inorganic particulates) should also be considered (Bay Institute).

Response: The issue of selenium in inorganic versus organic material has been addressed by specifying the maximum amount of organic selenium which, based on the NOAELs derived from the literature, would represent safe levels in wildlife feed. In addition, it is analytically very difficult to determine what fraction of suspended material in a water sample from the Bay is detritus, living organic matter, and inorganic particulates.

Comment: Support the proposed approach for implementing the State Enclosed Bays and Estuaries Plan, specifically the narrative water quality objective, and strongly recommend the direct incorporation of the subject water quality objective and State plans by reference (SWRCB).

Response: Noted.

Comment: The amendment should be modified to clearly define which waters are affected by the implementation plan (SWRCB).

Response: The MERS has been amended to specify precise segments of the Bay subject to immediate waste load allocations and reductons. Further specification of water bodies, particularly in the South and Central Bays will proceed after more accurate loading data have been obtained.

Comment: More explicitly describe the beneficial uses affected by existing levels of selenium in the food chain (SWRCB).

Response: In response to comments, the MERS has been amended to more precisely describe affected and potentially affected beneficial uses.

Comment: The amendment should clearly state how the Board will monitor the effectiveness of the implementation program, including assessment of selenium levels in indicator organisms and compartments and the protection of all levels of the estuarine communities and population (SWRCB).

Response: The monitoring half of this proposal will be more thoroughly developed in consultation with researchers in the field, other agencies currently collecting field data (CDFG, USFWS, USGS, etc.), dischargers, and other relevant parties. The goal is to use, as much as possible, already established monitoring programs (ie. the CA Mussel Watch, the Local Effects Monitoring Program being conducted by the dischargers, and the Board's Regional Monitoring Program, for example) and develop a detailed plan and schedule for a) conducting the monitoring, b) evaluating the results, and c) using site-specific data to adjust the literature-derived ecological assessment guidelines if necessary. The goal is to convene a task force to develop and oversee this detailed plan six months after the adoption of the proposed amendment.

Comment: The listing of San Francisco Bay as an impaired water body due to selenium was unfounded and improper (WSPA).

Response: The MERS is independent of the 304(l) listing and addresses several regulatory requirements as outlined in the staff document.

Comment: Oppose the gradual reduction strategy since there is no evidence it can be achieved (WSPA).

Response: Staff recognize that significant reduction in mass emissions of selenium from the refineries are likely to proceed in a stepwise manner–that is effective control mechanisms are installed when they become available, rather than incremental changes each year. At the same, some mechanism is needed to a) ensure the timely development and installation of controls, b) evaluate environmental conditions in light of reductions, and c) prevent increases in emissions in the interim.

Comment: Significant negative environmental impacts, such as hazardous waste production, would result from using existing technologies to reduce selenium emissions (WSPA).

Response: The environmental impacts associated with hazardous waste are related to how people and ecosystems are exposed to such material. At this point in time, selenium waste is currently being produced by the refineries and discharged into the Bay, thereby exposing the entire Bay ecosystem to selenium. To accurately judge the impact of this waste would require a comparative assessment of the environmental risks associated with air, water, or land disposal of the selenium-laden waste. At this point in time, it appears that a properly stabilized, solid waste would, by far, pose the least environmental risk.

Comment: Cost effectiveness of mass or concentration limits cannot be determined until selenium removal technologies are developed (WSPA).

Response: The choices made during the development of removal technologies will, to a large extent, determine the cost of emissions reductions. Also, we are convening a task force to oversee WSPA's technological study and avoid premature selection and installation of inefficient controls.

Comment: Support continued work on the development of technological controls and implementation options undertaken by WSPA (WSPA).

Response: Noted.

Comment: WSPA member companies participate in the collection of ecological baseline data from 1993-97 (WSPA).

Response: Agree.

Comment: Ecological monitoring should be continued until 2001 to provide a fair assessment of the ecological impact of refinery emissions reductions. No further reductions should be required prior to that date (WSPA).

Response: The timetable for refinery reductions in the MERS has been changed to allow for a longer period of time to assess levels in the Bay food chain after controls have been installed.

Comment: Studies of over 50 treatment technologies have not yet yielded a process which could be cost effectively implemented. Goal of WSPA study is to develop control technologies capable of reducing emission levels to 50 ug/l by December, 1997. Treatment systems would need to be employed at several refineries to reach the initial emission levels of the MERS timeline. Technological study would require an estimated 24-30 months from initial process design to start-up, presuming a good understanding of refinery selenium sources (WSPA).

Response: It is our understanding the process of designing controls and assessing refinery selenium sources was begun in 1990.

Comment: No acceptable control technologies currently exist, none has successfully passed the pilot stage. Premature process selection, driven by a sliding time scale, may result in less efficient selenium removal and higher than necessary environmental impacts (WSPA).

Response: Staff are actively encouraging broadening the review of potential treatment methods to ensure the most effective and environmentally sound processes are considered in the research and implementation process. See above comment on the function of the sliding timescale.

Comment: Disagree that the Environmental Checklist is the functional equivalent of and EIR because currently, no treatment technologies exist to evaluate (WSPA).

Response: Noted. See discussion in staff report.

Comment: Further study of whether the proposed amendment will cause a substantial increase in demand upon existing sources of energy or require the development of new sources is needed (WSPA).

Response: The revised MERS emphasized technological controls as a first step in reducing emissions. Such controls would likely not have any impact on supply or demand of crude.

Comment: A crude-based approach would, at best, achieve only marginal reductions in effluent selenium. More significant changes in crude slates would require major refinery modifications, process, safety, environmental, and economic reviews. It is not known that changes in crude selenium would result in proportional changes in effluent levels (WSPA).

Response: At this point in time, it does not appear that changing crude slates would achieve significant reductions of selenium emissions any faster than the timeframe in the proposed technological study. It also appears that technological controls would more efficiently and reliably reduce selenium loading in

the short term because: selenium content of crude is highly variable, the relationship between selenium input and outflow is highly complex and depends upon a wide range of factors such as time, the nature of processing and processing equipment, product, and treatment. A better understanding of selenium chemistry throughout the refinery process would be required before loading reductions could be predicted from changes in crude.

Comment: Any currently known treatment processes have the potential to achieve short-term objectives to the disadvantage of long-term objectives of waste reduction (WSPA).

Response: Selenium is a waste product and is currently being discharged to the Bay. See comment on hazardous waste production.

Comment: Concerned that the proposed 75% reduction level in the MERS is a step beyond the 50 ppb concentration-based limit. Use of the 1989-1992 baseline requires deeper reductions than if the current higher baseline were used (WSPA).

Response: The concentration-based limit is founded upon a water quality criterion which does not account for bioaccumulation of selenium in the food chain. This proposed strategy was specifically developed as an alternative to the 50 ppb concentration-based loading limit. The Board first took action on selenium loading levels in 1991, indicating levels at that time were too high. The years 1989-91 were used to define baseline emissions to a) be consistent with the State Pollutant Policy Document which defines current loading as the most recent three years and b) be consistent. Using a more recent baseline is not warranted.

Comment: Any reductions after 1998 (the projected timeframe for developing and installing control technologies which would meet a 50 ppb limit) would likely require sequential, high-cost capital projects at several refineries (WSPA).

Response: It is is also possible that improved understanding of selenium in refinery processes would result in less expensive, more effective means of control.

Comment: Support evaluation of any loadings reduction on aquatic communities (WSPA).

Response: Noted.

Comment: The MERS should be reviewed in light of information submitted to Board staff regarding selenium in effluent and the efficiency of certain operating units (Shell).

Response: See crude management discussion.

Comment: Discharge reductions should be technically achievable at the proposed time, consistent with the timetable provided in the WSPA joint study proposal (Shell).

Response: See discussion on distinction between the MERS and the December 1993 deadline, and the discussion on the timetable.

Comment: The ecological assessment guidelines should be revised to acknowledge any errors identified by Exxon Biomedical Research. In addition, all scientific evidence about the role of selenium as a nutrient and potential toxicant should be addressed (Shell).

Response: The ecological guidelines have been revised in response to comments and evidence of the

role of selenium as a nutrient discussed in the supplemental staff document.

Comment: As discussed in comments submitted by WSPA, the CEQA checklist findings on the increased demand for energy, the potential to achieve short-term goals to the disadvantage of long-term goals, and the need for substantial alterations to solid waste utilities should be changed (Shell).

Response: See comments above.

Comment: The Board should recognize the energy implications of alternatives, particularly the timing and need for refinery process modifications if different crudes are to be used. Specifically, the use of alternative sources of crude may require the importation of crude from outside CA (CEC).

Response: See discussion on crude management in the supplemental staff report.

Comment: Producing the new CA diesel fuel and reformulated gasoline may require process changes beyond those being proposed in the MERS. Air quality requirements and their impact on refineries should be considered in conjunction with selenium reduction strategies (CEC).

Response: Major process changes are being carried out or planned for Bay Area refineries to switch over to reformulated gasoline and diesel fuel (target date of 1995). It is projected that selenium emissions will increase as a result of these processes. The technological controls currently being studied would, in comparison, require far fewer refinery modifications than the reformulated fuels.

Comment: Support the MERS, see refinement of details such as specific ecological assessment guidelines, temporal and geographic units associated with emission limits, and methods for assessing compliance with ecological guidelines as proceeding concurrently with implementation of reduction measures. Tradable discharge permits should be considered as method for implementing this strategy (EDF).

Response: Noted.

Comment: Support directly limiting selenium loading rather than wait for improved scientific understanding of the transfer of selenium from the water column into sediments and the food chain to re-derive a site-specific water quality standard. Mass loading limits must be as enforceable as concentration-based limits (EDF).

Response: Noted. Mass loading limits in discharge permits are, for purposes of enforcement, no different than concentration-based limits.

Comment: Support adoption of schedule such as proposed timeline because new scientific understanding can be incorporated by changing the final cutback and provides dischargers with information required for investment decisions (EDF).

Response: Noted.

Comment: Water column concentration limits should be derived using literature values for algal bioconcentration factors, and can be adjusted to dissolved selenium levels found in the Bay using a generalized partition coefficient/ water concentration regression (EDF).

Response: This would require additional research as not enough data are available to derive this model. A water column guideline based solely on uptake data would not necessarily reflect dominant pathways

by which selenium was incorporated into the food chain (ie. dominant algal species may passively absorb Se, while less prevalent species may actively take Se up and be the major source of Se at higher trophic levels).

Comment: Limits on Se loading should be calculated separately for discrete geographical subunits of the Estuary and any subsequent limits for POTWs, urban runoff, and riverine sources derived separately for each region. Two of the subdivisions should be Suisun/Carquinez area, and the extreme South Bay (EDF).

Response: The northern geographical unit has been defined as San Pablo Bay, Carquinez Strait, and Suisun Bay. Defining the southern area is more complex--discharge, tissue, water column, and stream data suggest the presence of several hot spots and/or diffuse mass loadings, particularly along the western shore of the South Bay. The geographical definition of the southern reach will be defined after more information is available on Se in groundwater, runoff, water supply, and POTW discharge. Limits will be calculated separately for each type of source.

Comment: Consideration should be given to using a time-step shorter than one year in the reduction schedule because of pulses and difference between low- and high-flow conditions (EDF).

Response: These issues have been addressed in current permits by requiring dischargers to keep a running annual average and we expect to continue using this method. Furthermore, monitoring will take place throughout the year.

Comment: An emissions trading program should be set up for Se (EDF).

Response: This means of allocating loading limits has been considered and several issues would have to be resolved: institutional questions such as who would be responsible for auctioning and keeping track of allocations, how such a system would mesh with the legal requirements of the NDPES, and the design of equitable rules under which trading would be allowed.

Comment: Disadvantage of current proposal is that refineries are being required to reduce emissions to meet ecological guidelines in advance of similar controls on other loading sources (EDF).

Response: While the oil refineries in the northern part of the Estuary are responsible for the majority of selenium loading and are being required to reduce emissions, allocations will also be made to riverine and POTW sources. Reductions of selenium loading into the San Joaquin has been the focus of work at the Central Valley Board. At this time, we do not believe there is significant loading from other non-point sources. Future load allocations will continue to reflect new information, particularly an improved understanding of POTW loading, the source of Se to the POTWs, loading from groundwater sources (particularly in the South Bay), and the impacts of varying riverine flows on loading.

Comment: The staff report should be modified to address how estimated load reductions could be achieved by alternative control measures and the economic, social, and environmental consequences of implementing the measures (consistent with Porter Cologne). Specifically, the document does not address whether the proposed ecological assessment guidelines are reasonably attainable and the proposed strategy would result in the attainment of those guidelines (San Jose).

Response: Discussion are currently underway with the refineries to assess a wide range of possible control measures, with the goal being the development of the most efficient, environmentally sound, and cost-efficient removal measures. The loading limitations are based on a phased TMDL process and are specifically designed to take new scientific information into account while at the same time work

towards preventing further accumulation in the food chain. Appropriate control measures for POTWs and non-point sources will be considered, but only after a more detailed assessment of sources has been completed.

Comment: Object to the proposed ecological assessment guidelines as they would have the regulatory effect of numerical water quality objectives and should be subject to the same Porter Cologne and CEQA requirements as proposed objectives (San Jose).

Response: The assessment guidelines will be used, along with other information, to interpret the narrative objective. See discussion in supplemental staff report.

Comment: The proposed guideline for water is based on the most stringent values of those considered--this choice is not well-supported in the staff document. The water guideline should be subject to review by EPA, the scientific community, and the regulated community (San Jose).

Response: The water guideline is not included in the current MES, pending new information.

Comment: The proposed guideline for bivalves is based on a questionable NOAEL for wildlife feed, which was in turn based on three studies. This guideline should not be adopted without further scientific support. Most Mussel Watch data for the Bay exceed the proposed guideline (San Jose).

Response: The bivalve guideline has been revised to 4.5 ug Se/ g dw and changes have been made in the NOAEL review based on comments (see supplemental staff report). The guidelines will be revised as necessary to reflect new information. This comment does not clearly define what is adequate scientific support.

Comment: The sediment guideline is based on one study; a single study is not adequate basis for establishment of a numerical guideline intended as a measure of attainment with objectives (San Jose).

Response: See above discussions.

Comment: How would the proposed guidelines be used? Would mean, median, or maximum ambient values be used for comparison with the proposed guidelines? Would the guidelines be used for setting limits for individual dischargers? What reductions would be required in the South Bay if guidelines were exceeded in that area and how would such reduction levels be determined? (San Jose)

Response: The MERS lays out an iterative, phased process in which precisely these issues are to be addressed. We do not envision using a predictive model to back-calculate loading limits from tissue levels, although at some point in the future enough information may be available to support such a model. At this point in time, the knowledge-based guidelines would be used to more carefully assess the effect of loading reductions, the location of hot spots, and help pinpoint ecological impacts. A process of evaluating loading sources, possible control measures, and food chain levels in problem areas in the South Bay would be conducted to ultimately determine any required reductions.

Comment: The finding that selenium is producing adverse effects on beneficial uses is overstated. The staff report states: "levels of selenium...are a significant cause for concern," "detrimental biological effects may be occurring in the estuary's ecosystem," and that levels of selenium in organisms, suspended material, and water are significantly above background concentrations, with excessive levels of Se found in the food chain in the South Bay. The report implies that beneficial uses in South Bay are adversely impacted by these conditions (San Jose).

Response: The MERS follows the State Pollutant Policy Document and clearly states why and to what degree there is an absence of clear evidence that beneficial uses are protected from the accumulation of selenium in the food chain.

Comment: Object to the proposed strategy because it will impose arbitrary emission reductions on dischargers. It is impossible to demonstrate when elevated selenium concentrations no longer threaten sensitive Bay organisms (a stated endpoint for loading reductions). Concerns that problems to be corrected with this strategy are not clearly established, the relationship between present mass emissions and "problems" are unknown, conditions which would satisfy present concerns are not clearly defined, and the level of effort required by dischargers to comply is indeterminant (San Jose).

Response: The MERS is a phased process during which information and appropriate actions are simulataneously developed. Such a phased process is necessary to both prevent further degradation of water quality and address concerns about current levels of selenium in the Bay food chain while at the same time take into account the practical problems associated with loading reductions.

Comment: Proposed refinery emission reduction schedule is impractical and unachievable. Studies of more than 50 potential technologies have not identified a removal process which could meet a 50 ppb effluent limit without other environmental consequences. Improved technology could be implemented by 1997 under WSPA proposal, not before then (Exxon).

Response: Noted. See above discussions.

Comment: Unlikely any process could be implemented at a given refinery with flexibility to achieve proposed stepwise reductions. The overall level of reductions will require controls simultaneously at several refineries (Exxon).

Response: While stepwise improvements may prove to be impractical at any one refinery, loading reductions from the refineries as a group could be achieved on a stepwise basis.

Comment: Proposed schedule unlikely to support the concept of undertaking and relying on ecological assessments after each increment of reduction, particularly because the sediment may have served as a sink and may mask any effects of reductions in the short term (Exxon).

Response: Current information suggests that algal levels may respond quickly to changes in selenium loading, however, this issue needs to be more fully addressed as the protocol for monitoring and assessing food chain levels is further developed.

Comment: It is premature to debate whether mass or concentration based limits would be more effective until appropriate technologies are developed. Potential negative environmental impacts of the proposed amendments have not been fully addressed (Exxon).

Response: Limits will be based on protection of beneficial uses. See above discussion on hazardous waste generation and environmental impacts.

Comment: Support attention to other contributing sources, particularly increasing understanding of the contribution and control options for POTWs and riverine sources (Exxon).

Response: Noted.

Comment: Ecological guidelines should be applied well outside the initial zone of dilution, particularly

since the MERS is based on overall mass loading (Exxon).

Response: The MERS is based on limiting mass flow of selenium through the food chain. Monitoring may demonstrate that a significant amount of discharged selenium enters the food chain through primary producers in the initial zone of dilution. It may also demonstrate much more dispersed uptake.

Comment: Share concern over evidence of excessive bioaccumulation of Se in Bay organisms. MERS is scientifically sound and presents a reasonable and flexible plan for achieving compliance with narrative water quality objective. When completely implemented, the MERS should fully protect fish and wildlife from selenium toxicity (USFWS).

Response: Noted.

Comment: As more information on ecotoxicology is gathered, Board may wish to periodically review current ecological assessment guidelines and recommend a schedule for such reviews (USFWS).

Response: Noted.

Comment: Adding a term for selenomethionine to the assessment guideline for water might make the guideline substantially more sensitive (USFWS).

Response: A term for selenomethionine was not used in the derivation of the water column guideline because a) the biogeochemical cycling model suggested that any organic selenium in the water was the result of selenium already having entered the food chain and b) there was no relationship between organic selenium and levels in TSM. The water guideline has been removed from the MERS pending additional information on primary producer uptake.

Comment: In inland terminal-sink aquatic systems, water concentration is a strong determinant of biotic dosing. Why this does not appear to be true for the Bay should be a high research priority. Mass loading, however, ultimately drives determinants of biotic dosing and regulating loading as a means of achieving a desired ecological response is a scientifically sound strategy (USFWS).

Response: Noted.

Comment: Two studies have reported toxic effects for fish inhabiting environments with water column levels of selenium less than 15 ug/l (report by Hodson et al., 1980): teratogenic effects a mesocosm study with fathead minnows at 10 ug/l (Hermanutz, 1992) and acutely toxic bioaccumulation resulted under treatments of < 1ug/l selenomethionine in a microcosm study (USFWS, 1990) (USFWS).

Response: Noted.

Comment: Trend of increasing selenium levels in several species of wading birds nesting in the Bay has been observed (Hothem et al., 1992) (USFWS).

Response: Noted.

Comment: Mean liver levels of Se from birds in Chesapeake Bay ranged from 2.7 to 13.8 ug/g dw (Fleming et al., 1992) (USFWS).

Response: Noted.

Comment: Rallid (clapper rail family) eggs from Se-normal environments range from 0.4 to 2.9 ug/g dw, median geo. mean 1.4 ug/g. Suggests using 2.9 ug/g Se dw as guide for elevated levels in clapper rail eggs. In other taxa, egg concentrations as low as 3.9 ug/g dw have been associated with impaired immune function in hatchlings (USFWS).

Response: A guideline for selenium levels in rallid eggs has been added to the MERS.

Comment: Substantial amounts of inorganic Se may be bound to manganese oxides. One study has found high correlation between selenium and manganese concentrations in Bay waterfowl (Moller et al, in prep.); exposure to manganese-bound inorganic Se may be very different than Se exposure at Kesterson (USFWS).

Response: Noted.

Comment: Concerned with the possibility of curtailing or reducing the processing of San Joaquin crude at Bay Area refineries. Such a scenario would have a large impact on California oil producers and potentially increase tanker traffic through the Bay (CA Dept. Conservation).

Response: Noted. See above discussion on crude management.

Comment: Selenium removal studies have included: acidification and stripping (ineffective because form of Se in sour water stream not easily stripped or oxidized), ferric iron coprecipitation (generates 14-20 tons/d of sludge classified as hazardous), fixed bed anion exchange (Sorbplus showed a relatively low capacity and generates 5-10 tons/d of hazardous waste), anaerobic and aerobic biological processes (less than 50% removal). WSPA joint study projected to be completed in June, 1996 (WSPA).

Response: Noted.

Comment: Staff chose to use only those dietary NOELs lass than 10 ug Se/ g dw. We do not believe this is justified and feel that decisions should be based on as much dietary NOAEL information as possible (Exxon Biomedical).

Response: Levels below 10 ug/g dw were selected for the focus of this study because we judged there to be a general consensus that dietary levels above this caused adverse impacts on many aquatic organisms.

Comment: The NOAEL of 4 ug/g dw in feed from Heinz et al., 1990 was incorrectly calculated from a wet weight value. The correct value should be 4.5 ug/g dw (Exxon Biomedical).

Response: Assessment guidelines have been corrected for this.

Comment: Citation of Peterson and Nebeker (1992) duplicates Heinz et al. (1990). Use of Peterson and Nebeker (1992) gives a false impression that additional experimentation supports the 4 ug/g dw NOAEL (Exxon Biomedical).

Response: The staff report clearly indicated that the conclusion reached by Peterson and Nebeker (1992) was drawn directly from the Heinz paper, and, as their purpose was also to develop regulatory guidelines in accordance with EPA procedures, it was included in the report.

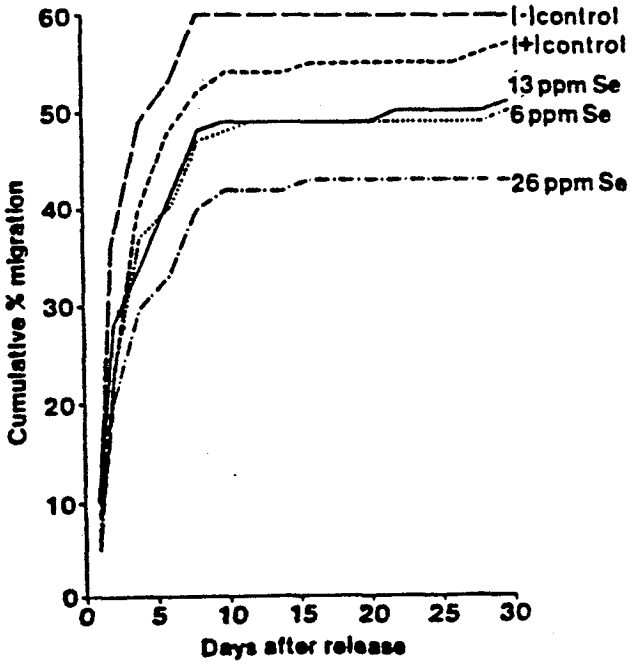
Comment: The NOAEL of < 6.5 ug/g dw was inappropriately taken out of context from a discussion point being made by Hamilton et al. (1986). The authors instead conclude that selenium concentrations

exceeding 13 ppm in food sources would adversely effect fall chinook salmon.

Text from Hamilton et al. (1986) cited in support of critique:
"All of these studies of waterborne trace elements, like our diet study with selenium, showed adverse effects on parr-smolt transformation at exposure concentrations lower than those causing acute and chronic effects on growth and survival in fresh water. Similarly, our dietary study with selenium-contaminated mosquitofish showed adverse effects on parr-smolt transformation of fall chinook at concentrations - ie. 6.5 ppm selenium - not affecting growth and survival" (comment interpreted this to mean that parr-smolt transformation tests were more sensitive than growth and survival tests)

"Based on the results of the present study, if selenium concentrations exceed 50 ppb in water or 13 ppm in food sources in the San Joaquin River or the Delta, fall chinook salmon would be adversely affected" (comment interpreted this to mean than a more appropriate NOAEL would be 13 ppm and not 6.5) (Exxon Biomedical).

Response: Both the text of the discussion and the data were considered. The authors statements are somewhat contradictory, one the one hand, they definitively argue that food levels of 13 ppm or greater are likely to have adverse effects. On the other, they also interpret their data as demonstrating adverse effects at 6.5 ppm. The 6.5 ppm value was chosen based on their reported data (reproduced here) which show very little difference between the 6.5 ppm treatment and the 13 ppm treatment. On the basis of information presented, it can not be definitively argued that 13 ppm caused an effect and 6.5 ppm did not.



Cumulative percentage downstream migration, over 30 days, of fall chinook salmon fed different amounts of selenium-contaminated *Gambusia* in freshwater for 34 days before they were released in a simulated stream, June 1985 (from Hamilton et al., 1986).

Comment: The parr-smolt experiment (Hamilton et al., 1986) did not include any experimental replication to ascertain the degree of variability of data for a given concentration. In order to form definitive conclusions, additional testing would be advisable. It is questionable that a reduction in migration of 5-6% would be significant in light of the fact that the controls demonstrated only 56-57 cumulative percent migration (Exxon Biomedical).

Response: The ecological assessment guidelines were derived solely on the basis of available data. Any information from future studies looking into issues such as the variability described above will be considered as it becomes available. From an ecological standpoint, the cumulative effects of small reductions in migration of salmon have been shown to be drastic.

Comment: Selenium concentrations in the Hamilton paper were reported as wet weight and not dry weight, where 16% of the diet was comprised of mosquitofish. The NOAEL should be adjusted accordingly (Exxon Biomedical).

Response: The NOAEL has been adjusted to reflect the moisture content of the diet fed to the chinook (84% Oregon Moist Pellet: 30.7% water, 0.5 ug Se/ g wet weight; 16% freeze-dried mosquitofish, 38 ug Se/ g dry weight).

Comment: Citations for Peterson and Nebeker (1992) should be reviewed and confirmed that selenium concentrations are dry weights. Once a definitive NOAEL is established, that paper should be cited rather than Peterson and Nebeker (1992) (Exxon Biomedical).

Response: When additional information on an NOAEL for mammalian growth has been published, it will be considered.

Comment: (Regarding Hamilton et al., 1990) The brackish water NOAEL of 18.2 ug Se/ g dry weight is most scientifically defensible test because they simulate conditions in the Delta (Exxon Biomedical).

Response: The freshwater tests in Hamilton et al. (1990) were conducted on much younger fish than the brackish water tests and thus offer additional information on the sensitivity of fish to selenium in the diet at different life stages. The NOAELs will be classified as brackish and fresh.

Comment: Uncertainty is introduced into Hamilton et al's (1990) experiment by using field-collected fish (referred to as the SLD diet–from the San Luis Drain) as a source of selenium. Other compounds, particularly boron, strontium, and chromium that were found in high levels in the fish may have been wholly or partially responsible for the difference between fish fed a diet enriched with selenomethionine (referred to as the Se-Meth diet) and those fed a diet enriched with field-collected food. Data from exposures to the field-collected fish should not be used. The results of the 90-day freshwater test are also questionable because control mortality was >32% between the 60th and 90th day, thus the 60th day freshwater NOAEL is most appropriate. In light of these factors, the most appropriate NOAELs are the freshwater 60 day NOAEL of 9.6 ug/g Se dw or the brackishwater 120 day NOAEL of 18.2 ug/g Se dw (Exxon Biomedical).

Response: The freshwater value for survival at 90 days on the Se-meth diet was the endpoint used in the staff report, only it was considered a LOAEL and not a NOAEL. Hamilton et al. (1990) report highly significant differences between control and treatment groups exposed to 9.6 ug/g Se dw in the diet (freshwater experiment–at 60 days) and 18.2 ug/g Se dw in the diet (brackish water experiment). These dietary concentrations, then, reflect levels at which adverse effects on survival or growth occurred and are LOAELs, not NOAELs. According to standard procedure, the next lowest value tested by the authors was reported as the NOAEL–namely 5.3 ug/g for the freshwater test. The brackish water

NOAEL of 9.6 ug/g will be added to the list.

Comment: The biomagnification factors derived from Lemly's (1985) study of a freshwater lake are inappropriate for several reasons. Converting values to dry weight, using levels in muscle tissue, and additional data for other species, the following biomagnification factors can be estimated at 0.25 to 0.40 for primary producers to primary consumers from Lemly's data. Biomagnification between primary producers and molluscs may also be derived from this paper and range from 0.5 to 0.71.

Based on a brief review of literature cited by Phillips (1988), the estimate of biomagnification from 3-4 along marine food chains after initial uptake by phytoplankton may be an appropriate estimation (Exxon Biomedical).

Response: Data presented by Liu et al. (1987) specifically address selenium accumulation in marine food chains and show selenium in benthic food chain (macroalgae, gastropods, crustaceans, anthozoa) increasing by 10-fold from primary producer to crustaceans (similar to bivalves) at the second trophic level, and an overall increase of 21-fold from the first to the third trophic level. The rest of the data presented in this paper suggest that Se does not increase more than 2-4 times over different trophic levels. Because the benthic pathway is likely to be more important in the Bay than in coastal waters, the greater biomagnification factors for that pathway must be taken into account. However, since the guidelines consider marine organisms as feed for wildlife, the 10-fold increase between first and second trophic levels is the most appropriate figure.

Comment: Staff use ratios for the relative uptake of selenite and selenate by algae derived from 3 water concentrations and four algal species tested by Vandermeulen and Foda (1988). Information on all five algal species should be used, the result is a selenite:selenate ratio of 25. The average Se^{+4}: Se^{+6} ratio reported for all species at all concentrations was 60. Since concentrations of selenium in the Bay range from 0.1 to 0.3 ug/l, the ratio of 25 is more appropriate for application to the Bay (Exxon Biomedical).

Response: Agree.

Comment: Staff make several assumptions in evaluating Cutter's data including: Se in TSM is organic and TSM is principally if not totally algae. The selected NOAELs are inherently stringent and based on organic selenium. There is evidence that not all the selenium in plants is organic. Thus, before using the TSM model, it should be verified that the selenium is predominantly Se-methionine. The assumption that TSM is principally algae is unfounded because chlorophyll a concentrations are not correlated with TSM concentrations. Thus, the model cannot accurately predict organic selenium concentrations in algae from water column selenite concentrations using TSM as a surrogate for phytoplankton. It is recommended the model not be used and studies undertaken to determine safe levels of selenium in the Bay (Exxon Biomedical).

Response: The water column guideline has been removed from the MERS pending new information. When that becomes available, the points made in this comment will be reconsidered.

Comment: Two other assumptions made in the model are that the relationship between selenium in TSM and selenite in the water column is linear, and that the regression can be used to extrapolate beyond the range of the data.The Board's model for relating selenium levels in TSM to dissolved selenite is:

TSM (ug Se/l) = 0.2 + 7.8 Se^{+4} r2= 0.61

an alternative model would be:

TSM (ug Se/L) = 1.65 * Se^{+4} /(0.082 + Se^{+4}) r2=0.63

Both models are of similar statistical quality and accurately predict TSM concentrations within the range of the data. Laboratory and field studies should be undertaken to define the relationship between dissolved selenite and selenium in TSM. Neither model should be used when Se^{+4} is outside 0.01 to 0.1 ug/l range, or TSM levels are outside 0.06 to 1.14 ug/g range (Exxon Biomedical).

Response: The water column guideline has been removed from the MERS pending new information. When that becomes available, the points made in this comment will be reconsidered.

Comment: Ecological assessment guidelines are based on minimal data with an associated high level of uncertainty, set without a clear understanding of natural levels of selenium in organisms at unimpacted sited, it is unclear whether reduction of mass loading will result in measurable improvement within the specified time frame, and there is no clear explanation of how compliance with the assessment guidelines will be determined (Exxon Biomedical).

Response: The MERS proposes improving understandings of selenium biogeochemical cycling in the Bay between the beginning of the proposed reduction schedule and the time by which loadings will be reduced by 75%, using additional information to refine the guidelines as necessary and thus reducing uncertainty. Comment regarding measurability of improvement and compliance is noted and discussed above.

Comment: The sediment guideline is based on a single study designed to evaluate the adsorption efficiencies of selenium in bivalves, not to determine accumulation under realistic environmental conditions. Using the 1.5 ug/g dw estimate as a sediment guideline even though there is a high level of uncertainty associated with it. Recommend validation study before the guideline is adopted (Exxon Biomedical).

Response: The comment does not clearly state what level of certainty is appropriate.

Comment: The report does not adequately address natural background levels of selenium in each environmental compartment. The proposed assessment guideline for bivalves is 3.0 ug/g Se dw and should be adjusted to a) reflect the review of the NOAELs and b) better reflect tissue data from reference sites.

Comment includes frequency distribution diagrams of selenium in coastal and Bay bivalves, supporting claim that background levels of selenium in the region are naturally high and bivalve levels are not elevated compared to reference sites with the exception of a small number of samples from caged mussels within zones of initial dilution. The proposed ecological assessment guideline is unrealistic since approximately 55% of the bivalves from reference sites would exceed it (Exxon Biomedical).

Response: The "reference" site data used to compile the frequency distributions referred to in the comment included State Mussel Watch stations at Samoa Bridge (next to paper mills in Humboldt Bay) and Morro Bay Boat Works. It is inappropriate to assume all coastal sites are reference sites, and as in the original staff report, we are only using data from stations designated as reference sites by the State Mussel Watch from Pacific Grove north. Additional data on selenium levels in bivalves has become available and is presented graphically in the main text of the supplemental staff document below (only data for which dry weight values were reported were used in these graphs due to the variability in moisture content–all available bivalve data are listed in Appendix B), and show that there are specific locations where bivalve tissue levels are much higher than background (an appropriate EDL for mussels is 3.2 ug/g dw). The bivalve guideline has also been changed to 4.5 ug Se/ g dw.

NUTRITIONAL REQUIREMENTS FOR SELENIUM BY ALGAE

Algae	Form	Added* Selenium Concentration	Algal Response	Citation
marine chrysomonads	selenite	9.87 µg/g/L	optimal growth	Pintner and Provasoli, 1968
		<9.87 µg/L	decreased growth	
Fucus spiralis	selenite	2.6 µg/L	optimal growth	Fries, 1982
		0.79 µg/L	decreased growth	
	selenate	0.79-2.6 µg/L	optimal growth	
Thalassiosira psuedonana	selenite	<0.08 µg/L	decreased growth	Price et al., 1987
	selenate	79-790 µg/L	optimal growth	
		<7.9 µg/L	decreased growth	
Stephanodiscus hantzschii	selenite	0.11 µg/L	50-fold increase in biomass	Lindstrom, 1983
		>2 µg/L	highest mean growth rate	
Chrysochromulina breviturrita	selenite	10-100 µg/L	optimal growth	Wehr and Brown, 1984

*Amount of selenium added to algal culture medium; the culture medium may have contained additional trace levels of selenium occurring as trace contaminants from other ingredients.

NUTRITIONAL REQUIREMENTS FOR SELENIUM BY ZOOPLANKTON

Zooplankton Species	Added* Se Concentration	Other Factor	Zooplankton Response	Citation
Daphnia magna and *Daphnia pulex*	<0.1 µg/L	low dissolved organics	cuticle deterioration; dead by 2nd or 3rd molt	Keating and Dagbusun, 1984
	<0.1 µg/L	high dissolved organics	cuticle deterioration; extinct by 18th generation	
	<0.1 µg/L		cuticle deterioration	
	0.5 µg/L	low dissolved organics	cuticle deterioration	
	1.0 µg/L		healthy animals	
Ceriodaphnia dubia	<2 µg/L	25 C	high percentage of aborted eggs	Winner, 1989
	2 µg/L		significant decrease in egg abortion	
Ceriodaphnia dubia	<2 µg/L		decreased reproduction	Cowgill et al., 1990
	2 µg/L		healthy reproduction	
Daphnia magna	24 µg/L in algal med.	exposure through food	decreased toxicity of cadmium	Winner and Whitfield, 1987
Daphnia pulex	5 µg/L		decreased toxicity of copper	Winner, 1984
Ceriodaphnia dubia	2 µg/L		decreased toxicity of sodium chloride	Cowgill, 1987

*Amount of selenium added to algal culture medium; the culture medium may have contained additional trace levels of selenium occurring as trace contaminants from other ingredients.

Comment: It is unlikely that a single value guideline could be appropriately applied to all plant species in the Bay. Se concentrations in marine plankton from around the world range from 0.5 to 1.95 ug Se/g dw (Liu et al., 1987); data from uncontaminated freshwater lakes range from 0.62 to 1.03 ug Se/g dw. Recommend background and additional data be used to determine if proposed algal assessment guideline is appropriate and achievable (Exxon Biomedical).

Response: Noted. Again, the highest research priority is determining selenium uptake rates for primary producers in the Bay, including a comparison of to other estuarine environments.

Comment: The one year allocated to reviewing monitoring data after a 75% reduction in mass loading has occurred may not be adequate to determine if the program has been effective (Exxon Biomedical).

Response: The refinery reduction timetable has been changed to include more time for such review.

Comment: Contribution from riverine sources has not been fully considered in establishing true background levels and loading from these sources may mask any immediate effect of refinery loading reductions and may influence the time it takes to reduce food chain concentrations (Exxon Biomedical).

Response: Noted. Loading from these sources will also be considered. See above discussions.

Comment: Methods for evaluating data and determining compliance need to be clearly defined. Taking, for example, the average TSM concentrations in five segments of the Bay and comparing them to the proposed 0.7 ug Se/g TSM, no mean concentrations were significantly higher than the guideline (1-sided T-test, p=0.05) (Exxon Biomedical).

Response: Agree. The next step in the MERS is to develop exact methods for monitoring, evaluating data, and a schedule for reevaluating assessment guidelines given new information.

Comment: There is a need to conduct a sensitivity analysis to determine level of selenium reduction needed to meet the Board's ecological assessment guidelines for each environmental compartment of concern (Exxon Biomedical).

Response: It is not clear there are enough data to even estimate this, particularly since the mass flow through major food chain pathways are not even known.

Comment: Numerous authors have suggested the ecological assessment guideline for water would be less than optimal for survival, growth, and reproduction of several species of algae and zooplankton. Thus it is critical that appropriate levels of selenium not be overprotective (Exxon Biomedical).
[reproduce tables here]

Response: First, the benchmark used by authors cited in presented tables is inappropriate. "Optimal" algal growth as defined for these laboratory experiments is a value judgement and ignores the problem with excessive algal growth in natural aquatic systems. The Basin Plan also contains language which states that "water shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses." Second, observed selenium levels in the Bay are orders of magnitude below most of the experimental concentrations, yet algae and zooplankton communities exist here. Thus, the data presented in the comment appear to have little relevance. More appropriate data could be derived from studies using water column and food levels closer to those generally found in estuarine systems and a more appropriate endpoint for evaluating nutritional needs.

Comment: It remains debatable whether selenium actually biomagnifies or whether slightly increasing Se levels in the food chain is the result of a highly efficient transfer of Se (Exxon Biomedical).

Response: According to Liu et al. (1987), Se:carbon ratios are roughly the same as trophic levels increase, but

this still results in slightly higher tissue levels in many food chains--so there is an effective biomagnification.

Comment: Seleno-methionine is the forms which most efficiently transfers through the food chains, is the most toxic, and takes the longest time to eliminate from tissue, yet little data on selenomethionine levels is presented in the MERS (Exxon Biomedical).

Response: As additional data become available, they will be incorporated into the ecological assessment guidelines.

Comment: Not all selenium in plants is selenomethionine. Data from 2 studies indicate that Se-meth. may only be 15-50% of total selenium in seleniferous cabbage and wheat. It is impossible to accurately predict safe levels of selenium in the Bay without knowing how much of Se in the plants is Se-meth (Exxon Biomedical).

Response: This issue has been addressed by specifying the level of organic selenium in primary producers rather than total.

Comment: In light of information discussed above, adoption of the ecological guidelines should be postponed. It is important to identify safe levels of the critical forms of selenium and areas within the Bay that are at risk (if any). Once accomplished, efforts could focus on those areas to achieve maximum benefit. The current MERS provides no estimate of the benefit to be gained by adoption (Exxon Biomedical).

Response: The benefit of the proposed MERS includes avoiding increases in and long-term enrichment of the food chain before beneficial uses are severely impacted.

Comment: Two dissimilar strategies for controlling selenium discharges were proposed in the MERS: establishing site-specific water quality criteria based on limited information (a familiar and fairly defensible means of enforcing reductions) and calculating acceptable loadings from assessments of ecological effects (a method prone to endless disputes, particularly when those effects are unknown, disputed, or unquantifiable) (EOA/ Sunnyvale).

Response: The MERS does not propose calculating acceptable loadings from assessments of ecological monitoring data. Rather, it proposes an iterative process of incorporating new information about selenium levels in environmental compartments, coupled with loading limits. That process may entail ongoing discussions among all involved parties, but it also allows action to be taken to prevent further degradation of water quality while at the same time making use of all available knowledge.

Comment: The derivation of the ecological assessment guidelines has not been peer reviewed, it may be impossible to determine whether they are being met (standardized testing protocols for sampling and testing organisms don't exist, and no guidelines for interpreting compliance are proposed)(EOA/ Sunnyvale).

Response: The proposed ecological assessment guidelines are included in the Basin Plan amendment to clearly lay out the available information with which the narrative water quality objective will be interpreted. See discussions above.

Comment: The Board should not adopt these flawed numbers and assumptions into the Basin Plan because: there is no evidence that the quality of the Bay's aquatic ecosystem is currently being degraded by selenium: potential effects are only surmised from studies of other species and other environments; a regulatory program is already in place and refinery dischargers are unable to develop new technologies fast enough to meet the proposed schedule; these mandated reductions allow an opportunity to interpret and calibrate staff's model of selenium cycling (EOA/ Sunnyvale).

Response: The first comment suggests withholding action until a significant ecological impact is identified (with some degree of certainty). Current laws and regulations require the protection of beneficial uses: the beneficial use of hunting ducks from Suisun bay has been impaired, and available information on selenium

in aquatic systems suggests that additional beneficial uses may currently or would be impaired if selenium loadings were to increase. The protection of beneficial uses requires considering reasonable means for preventing irreversible damage before it occurs. The second comment has been addressed in greater detail above. The third comment, to a large extent, reflects the intention of the MERS proposal.

Comment: The Board should direct that reductions already mandated be enforced. Concurrently, a technical review committee evaluate the appropriateness of the data used in the MERS report, including a review of sampling protocols and analytical test methods to ensure standardization of data, and identify data required for a scientifically defensible mass emission reduction strategy (EOA/ Sunnyvale).

Response: After the task force to review development of refinery control technologies is operational, the intent of the MERS was to convene a second group to do precisely this. Some testing protocols are currently being addressed by the WSPA study. The major research priorities are outlined in the staff report accompanying these responses.

Comment: Public workshops or informal meetings should be held with discharger groups to discuss economics and technical viability of selenium treatment alternatives, the generation of hazardous materials, and possible institutional arrangements for emissions trading (EOA/ Sunnyvale).

Response: These are currently being developed.

Comment: The statement in the staff report "Toxic levels of selenium in wildlife feed can not be predicted from water column concentrations but can be prevented by limiting the total uptake of selenium into the food chain" is misleading because it assumes current food chain levels are toxic or approaching a toxic level. There is no evidence to show current selenium levels are adversely affecting wildlife and no background data for Bay wildlife (EOA/ Sunnyvale).

Response: See above discussions.

Comment: Language in the proposed amendment states that selenium concentrations found in Bay organisms indicates that the narrative objective is not currently attained in San Pablo Bay, Suisun Bay, and the South Bay. It has not been shown that these organisms have been or will be degraded as a result of waste discharges (EOA/ Sunnyvale).

Response: Tissue levels in many organisms found in these locations have been found to be significantly above background levels, reflecting a degradation of their feed source and possible adverse impacts on those organisms themselves.

Comment: The proposed MERS commits the Board to imposing a mass emission reduction strategy on POTWs after June, 1993 if loading from these sources is also significant. Even if POTWs are discharging measurable concentrations, it could take several years to determine if loadings were causing any environmental impacts or that benefits could be achieved through reductions (EOA/ Sunnyvale).

Response: The proposed MERS places a cap on current loadings and further investigations into the sources of these loadings and, if necessary, appropriate reductions and controls.

Comment: The proposed amendment would require POTWs to submit additional monitoring data and refers to a target detection limit of 0.01 ug/l. Commercial labs queried to date indicate that detection limits less than 1 ug/l are not available--species-specific analyses may be more difficult to obtain. Same comment for proposed stormwater monitoring (EOA/ Sunnyvale).

Response: This is a misinterpretation if the proposed amendment. No additional monitoring data would be required, lower detection limits are only being requested from those dischargers currently not detecting selenium in their discharge and for which we have reason to believe loadings levels are much lower than

calculated to date. Finally, several dischargers are currently submitting monitoring data with 0.5 ug/l detection limits indicating that analytical methods more precise than 1 ug/l are readily available. Also, the June 30, 1993 deadline was proposed last fall with the intention of giving involved parties a reasonable amount of time to accommodate the requests. Since then, many dischargers have already begun to submit more precise selenium monitoring results. The deadline has been revised due to the length of time since the proposed amendment was initially drafted.

Comment: The figure presenting selenium loading from refineries, POTWs, and riverine sources does not indicate what flow values were used in the calculations. Actual rather than design flow values should be used (EOA/ Sunnyvale).

Response: Actual flow values as reported in the self-monitoring reports were used.

Comment: Language following the proposed refinery emission reduction schedule may mislead reader to believe POTWs are the cause of excessive levels of selenium in the food chain. Suggest using "elevated" rather than "excessive" since no limits have been established yet (EOA/ Sunnyvale).

Response: Noted. Currently, some of the information on selenium in the South Bay attributes most if not all loading to the POTWs (Cutter, 1989, 1990; Gilliom, 1989). Other data on selenium levels in South Bay water supply, effluent, and Coyote Creek upstream of the San Jose/Santa Clara discharge suggest much more complex loading patterns (seasonal variations, possibility of seleniferous soil sources, etc.: South Bay Dischargers' Association Dec. 1981-Nov. 1986 report). The bivalve data for the South Bay also suggest that areas in which the food chain is enriched are localized. See above discussions.

Comment: The final paragraph of the amendment doesn't make regulatory sense. Local monitoring data should be evaluated to first establish baseline levels, more extensive water quality data is needed to supplement and verify that found by Cutter, it is questionable whether interim reductions could be successfully monitored over such a short period of time, and no baseline currently exists (EOA/ Sunnyvale).

Response: As the entire Bay may have been affected by years of anthropogenic selenium discharge, it is difficult to determine what natural baseline levels should be. Since the staff report was written, preliminary water quality data from samples taken in 1991 and 1992 throughout the Bay has been received--the data show very similar patterns and levels to data collected earlier. It is unclear from the comment what the specific goal (ie. what degree of certainty should be attained?) of supplementing/ verifying earlier data should be. Comment on timing of reductions and monitoring of results addressed above.

Comment: A scenario of what could happen under the proposed MERS if local elevated Se levels (in potentially transitory organisms/ particulates) were found is an enormous receiving water monitoring effort to establish the exact source of the selenium loading; these efforts would be based on a guideline that has not received scientific peer review. Also, it is not clear how exceedance of one guideline would be interpreted. The discharge community needs to know what the Board's policy and procedures will be before embarking on expensive receiving water monitoring (EOA/ Sunnyvale).

Response: The MERS lays out a proposed policy for simulatenously limiting selenium loading and addressing new information as it becomes available. See above discussion on further developing the process by which ecological guidelines will be used.

Comment: Agree that a mass emission reduction strategy is conceptually more logical than concentration-based limits, but disagree that the ecological assessment guidelines are the best way to implement the MERS (EOA/ Sunnyvale).

Response: Noted.

Comment: Fast-paced loadings reduction schedules inappropriate because a) no evidence to support assertion

that current selenium levels are degrading aquatic resources, b) the ecological assessment guidelines may be wrong since they have not undergone scientific review, c) sources and loadings have not been thoroughly characterized, including rationales and methodology for deriving riverine loading values (EOA/ Sunnyvale).

Response: See discussion above with respect to first comment. The comment regarding the potential error of the ecological assessment guidelines implicitly suggests that a particular level of certainty should be attained (ie. a more exact understanding of food chain impacts on Bay species) before any ecological guidelines are adopted. The comment, however, does not make clear what level of certainty should or could be attained. In addition, the two staff reports on selenium have been circulated widely, comments sought and received from many scientific experts, and changes made to the proposal. It is unclear exactly what type of "scientific review" is being proposed in the comment letter and exactly how such review differs from what has already been done. Finally, as in the above discussions, better definition of sources and loadings, particularly for the South Bay is the immediate goal of the proposed MERS (ie. better detection limits so as to better characterize loadings from POTWs). Riverine loading, particularly from the San Joaquin, will also be the focus of additional staff work (EOA/ Sunnyvale).

Comment: Appropriate weight should be given to the fact that bioaccumulation potential is likely to be species specific. Such information is currently not available for Bay organisms and uptake rates cannot be verified without further study (EOA/ Sunnyvale).

Response: The highest research priority is to develop a better understanding of precisely these factors.

Comment:In reviewing the Hamilton et al (1990) article, we could find no obvious references to the NOAEL values listed in the staff report (EOA/ Sunnyvale).

Response: See above discussion on the NOAEL derived from the paper by Hamilton et al. (1990).

Comment: No mention of the hatchability tests performed by Heinz et al. (1990) were observed, nor was there any obvious discussion of threshold levels (EOA/ Sunnyvale).

Response: An error was made in that the NOAEL is for survival of 6-day old ducklings and not strictly hatchability. Also, the concept of threshold was addressed by reference to Skorupa and Ohlendorf (1991).

Comment: Without reviewing every reference cited in the staff report, it would appear that the use of an NOAEL of 4-6 ug/g selenomethionine is inappropriate until further scientific review (EOA/ Sunnyvale).

Response: See above discussion.

Comment: Use of limited data to establish an effective bioconcentration factor is problematic because the database is insufficient to assess variability in uptake rates according to species, season, and location, additional sampling should be performed to assess ambient levels and distribution of selenium species, and a full literature review performed to better establish the relationships between water column values and those in the food chain. These studies should be peer reviewed (EOA? Sunnyvale).

Response: Again, it is unclear what degree of certainty in variabilities described above should be attained, additional sampling has been performed and is called for in the MERS, and the staff report presents a summary of all currently available information on water column: food chain relationships in the scientific literature resulting from an exhaustive review.

Comment: Using the 20:1 ratio to derive an equation relating selenite and selenate levels to levels in TSM is problematic because the strength of the correlation between selenate and TSM concentrations should be, according to this approach, roughly the same as the correlation between selenite and TSM concentrations. However, the former is much weaker (EOA/ Sunnyvale).

Response: The water column guideline has been removed from the MERS pending new information. When that becomes available, the points made in this comment will be reconsidered.

Comment: Selenium species found in the South Bay by Cutter were selenide and elemental selenium during April 1986, but selenate in September 1986. Attribution of selenium in South Bay to POTW discharge despite this difference was not explained but based on an earlier report by Conomos et al. (1979). We find no basis for Cutter's conclusions regarding sources in the South Bay until a full evaluation of non-urban runoff, soil types, influx, and geochemical cycling in the South Bay and from the northern reaches. Several additional sources should be considered: leaking oil barges (US Navy and others), ballast water discharges, and input from abandoned mines and geysers (EOA/ Sunnyvale).

Response: Noted. See above discussions. Information on such potential sources is welcome.

Comment: Staff report does not discuss fate and/or removal from the Bay to the ocean. Further data needs and studies on the geochemical cycling of selenium in the Estuary should be addressed and commitments from the Board to administrate these studies should be discussed (EOA/ Sunnyvale).

Response: The highest research priority is to assess uptake of selenium by primary producers. Additional studies may be useful in reducing the level of uncertainty associated with the current state of knowledge.

Comment: Other issues which were not addressed in the MERS: how it would be implemented (ie. immediate requirements by copy of letter from Executive Officer, inclusion of requirements during permit revisions, or amendments to NPDES permits), whether receiving water monitoring be initiated as a joint discharger effort, the frequency and duration of monitoring necessary to demonstrate compliance, sampling and test procedures accepted for tissue and sediment samples, and how the ecological assessment guidelines will be reviewed for compliance (EOA/ Sunnyvale).

Response: See above discussions on development of specific monitoring procedures.

Comment: Bay should be divided into water segments for monitoring of compliance (EOA/ Sunnyvale).

Response: Agree. Segments in the North Bay are San Pablo Bay, Carquinez Strait, and Suisun Bay. Segments in the South Bay will be defined when additional information becomes available (EOA/ Sunnyvale).

APPENDIX B: ENVIRONMENTAL CHECKLIST

After review of comments submitted on the proposed Mass Emission Reduction Strategy, staff have concluded that process and treatment selenium control strategies for the petroleum refineries are much more likely to be effective at reducing mass emissions than shifting from high- to low-selenium crude sources. As a result, item 15 b on the original checklist has been changed to "No." No other changes have been made. Responses to comments on other items of the checklist are in the main text of this report.

I. Background

1. Name of Proponent:
   San Francisco Bay Regional Water Quality Control Board

2. Address and Phone Number of Proponent:
   2101 Webster Street, Suite 500
   Oakland, CA 94612
   (510) 286-0702

3. Date Checklist Submitted:
   June 16, 1993

4. Agency Requiring Checklist:
   Resources Agency

5. Name of Proposal, If Applicable:
   Amendments to the Water Quality Control Plan,
   San Francisco Bay Basin: Mass Emission Reduction Strategy for Selenium

II. Environmental Impacts:

(Explanations of all "yes" and "maybe" answers are provided on attached sheets.)

	Yes	Maybe	No
1. Earth. Will the proposal result in:			
a. Unstable earth conditions or changes in geologic structures?			x
b. Disruptions, displacements, compaction or overcovering of the soil?			x
c. Change in topography or ground surface relief features?			x

	Yes	Maybe	No
d. The destruction, covering or modification of any unique geologic or physical features?			x
e. Any increase in wind or water erosion of soils, either on or off the site?			x
f. Changes in deposition or erosion of beach sands, or changes in siltation, deposition or erosion which may modify the channel of a river or stream or the bed of the ocean or any bay, inlet or lake?			x
g. Exposure of people or property to geologic hazards such as earthquakes, landslides, mudslides, ground failure, or similar hazards?			x
2. Air. Will the proposal result in:			
a. Substantial air emissions or deterioration of ambient air quality?			x
b. The creation of objectionable odors?			x
c. Alteration of air movement, moisture or temperature, or any change in climate, either locally or regionally?			x
3. Water. Will the proposal result in:			
a. Changes in currents, or the course of direction of water movements, in either marine or fresh waters?			x
b. Changes in absorption rates, drainage patterns, or the rate and amount of surface runoff?			x
c. Alterations to the course or flow of flood waters?			x
d. Change in the amount of surface water in any water body?			x
e. Discharge into surface waters, or in any alteration of surface water quality, including but not limited to temperature, dissolved oxygen or turbidity?		x	

	Yes	Maybe	No
f. Alteration of the direction or rate of flow of ground waters?			x
g. Change in the quantity of ground waters, either through direct additions or withdrawals, or through interception of an aquifer by cuts or excavations?			x
h. Substantial reduction in the amount of water otherwise available for public water supplies?			x
i. Exposure of people or property to water related hazards such as flooding or tidal waves?			x
4. Plant Life. Will the proposal result in:			
a. Change in the diversity of species, or number of any species of plants (including trees, shrubs, grass, crops, and aquatic plants)?		x	
b. Reduction of the numbers of any unique rare or endangered species of plants?			x
c. Introduction of new species of plants into an area, or in a barrier to the normal replenishment of existing species?			x
d. Reduction in acreage of any agricultural crop?			x
5. Animal Life. Will the proposal result in:			
a. Change in the diversity of species, or numbers of any species of animals (birds, land animals including reptiles, fish and shellfish, benthic organisms or insects)?		x	
b. Reduction of the numbers of any unique, rare or endangered species of animals?			x
c. Introduction of new species of animals into an area, or result in a barrier to the migration or movement of animals?			x
d. Deterioration to existing fish or wildlife habitat?			x

		Yes	Maybe	No
6.	Noise. Will the proposal result in:			
	a. Increase in existing noise levels?			x
	b. Exposure of people to severe noise levels?			x
7.	Light and Glare. Will the proposal produce new light or glare?			x
8.	Land Use. Will the proposal result in a substantial alteration of the present or planned land use of an area?			x
9.	Natural Resources. Will the proposal result in:			
	a. Increase in the rate of use of any natural resources?			x
	b. Substantial depletion of any nonrenewable natural resource?			x
10.	Risk of upset. Will the proposal involve:			
	a. A risk of an explosion or the release of hazardous substances (including, but not limited to, oil,, pesticides, chemicals or radiation) in the event of an accident or upset conditions?			x
	b. Possible interference with an emergency response plan or an emergency evacuation plan?			x
11.	Population. Will the proposal alter the location, distribution, density, or growth rate of the human population of an area?			x
12.	Housing. Will the proposal affect existing housing, or create a demand for additional housing?			x
13.	Transportation/Circulation. Will the proposal result in:			
	a. Generation of substantial additional vehicular movement?			x
	b. Effects on existing parking facilities, or demand for new parking?			x

		Yes	Maybe	No
	c. Substantial impact upon existing transportation systems?			x
	d. Alterations to present patterns of circulation or movement of people and/or goods?			x
	e. Alterations to waterborne, rail or air traffic?			x
	f. Increase in traffic hazards to motor vehicles, bicyclists or pedestrians?			x
14.	Public Services. Will the proposal have an effect upon, or result in a need for new or altered governnmental services in any of the following areas:			
	a. Fire protection?			x
	b. Police protection?			x
	c. Schools?			x
	d. Parks or other recreational facilities?			x
	e. Maintenance of public facilities, including roads?			x
	f. Other governmental services?			x
15.	Energy. Will the proposal result in:			
	a. Use of substantial amounts of fuel or energy?			x
	b. Substantial increase in demand upon existing sources of energy, or require the development of new sources of energy.			x
16.	Utilities. Will the proposal result in a need for new systems, or substantial alterations to the following utilities:			
	a. Power or natural gas?			x
	b. Communications systems?			x
	c. Water?		x	
	d. Sewer or septic tanks?		x	

	Yes	Maybe	No
e. Storm water drainage?		x	
f. Solid waste and disposal?		x	
17. Human Health. Will the proposal result in:			
a. Creation of any health hazard or potential health hazard (excluding mental health)?			x
b. Exposure of people to potential health hazards?			x
18. Aesthetics. Will the proposal result in the obstruction of any scenic vista or view open to the public, or will the proposal result in the creation of an aesthetically offensive site open to public view?			x
19. Recreation. Will the proposal result in an impact upon the quality or quantity of existing recreational opportunities?			x
20. Cultural Resources.			
a. Will the proposal result in the alteration of or the destruction of a prehistoric or historic archaeological site?			x
b. Will the proposal result in adverse physical or aesthetic effects to a prehistoric building, structure, or object?			x
c. Does the proposal have the potential to cause physical change which would affect unique ethnic cultural values?			x
d. Will the proposal restrict existing religious or sacred uses within the potential impact area?			x

	Yes	Maybe	No
21. Mandatory Findings of Significance.			
a. Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?			x
b. Does the project have the potential to achieve short-term, to the disadvantage of long-term, environmental goals? (A short-term impact on the environment is one which occurs in a relatively brief, definitive period of time while long term impacts will endure well into the future).			x
c. Does the project have impacts which are individually limited, but cumulatively considerable? (A project may impact on two or more separate resources where the impact on each resource is relatively small, but where the effect of the total of those impacts on the environment is significant).			x
d. Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?			x

IV. Determination:

X On the basis of this initial evaluation: I find that the proposed project COULD NOT have a significant effect on the environment, and a NEGATIVE DECLARATION will be prepared.

___ I find that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because the mitigation measures described on an attached sheet have been added to the project. A NEGATIVE DECLARATION WILL BE PREPARED.

___ I find the proposed project MAY have a significant effect on the environment, and an ENVIRONMENTAL IMPACT REPORT is required.

6/21/93
DATE

SIGNATURE

For:
San Francisco Bay Regional
Water Quality Control Board

ENVIRONMENTAL CHECKLIST: *explanations.*

3.e The proposal may result in improvements to surface water quality, due to reductions in selenium loading to the Bay. Based on technical studies supporting this proposal, it is likely that reducing mass loading will increase rather than result in any decrease in the protection of beneficial uses in the Bay.

4.a Reduced selenium levels in the Bay could result in greater numbers or greater diversity of aquatic plants. Based on current knowledge summarized in the technical report, it is too speculative to determine the degree to which diversity may be affected.

5.a Reduced selenium levels in the Bay could result in greater numbers or greater diversity of aquatic organisms. Based on current knowledge summarized in the technical report, it is too speculative to determine the degree to which diversity may be affected.

16.c If POTWs are significant sources of selenium due to storage of water in reservoirs with seleniferous soils, some alteration of water supply methods may be required to reduce mass loading into San Francisco Bay. It is too speculative at this point to determine whether there would be any adverse impacts as a result of possible changes.

16.d The proposed mass emissions strategy for selenium may require reductions in mass loading from sewage treatment plants. It is unlikely that such alterations would result in adverse impact as there will likely be many options for reducing selenium loading that have no adverse impacts such as source control measures.

16.e Information obtained in the future through this action may indicate significant sources of selenium in stormwater runoff. If this is the case, control measures may require some alterations to drainage and/or treatment. It is too speculative to assess the potential impact of possible alterations at this point.

16.f. Treatment technologies eventually developed and installed to reduce mass loading of selenium may increase solid waste. However, as the technologies have not yet been determined, it is too speculative at this point to assess the potential impact of waste generation.

APPENDIX C: Bivalve Data

REFERENCE SITES	Ref	Date	Species	Se (ug/g dw)	Range (est. from wet weight)
Trinidad Head (Mussel Watch Reference Site for *Mytilus sp.*)	1	1/82	RCM	2.73	
	1	9/82	RCM	3.20	
Humboldt Bay (reference site for *Crassostrea gigas*)	6	1/87	Oyster		5-8
	3	1992	Oyster	2.6	
Drake's Bay (ref. site for *Crassostrea gigas*)	3	1992	Oyster	1.3	
Bodega Head (reference site for *Mytilus* sp.)	1	8/81	RCM	1.80	
	1	10/81	RCM	1.97	
	1	8/82	RCM	2.73	
	1	8/85	RCM	3.06	
	1	8/86	RCM	3.12	
	6	Fall 86	TCM		2.9-3.3
	1	1989	RCM	2.37	
	1	1989	RCM	2.30	
	3	1992	RCM	1.3	

SOUTH BAY	Ref	Date	Species	Se (ug/g dw)	Range (est. from wet weight)
Coyote Creek	6	Fall 86	TCM		2.0-2.4
	6	Fall 86	TCM		3.6-4.0
	6	Fall 86	TCM		4.2-4.6
	3	1991	*Corbicula*	3.1	
	3	1991	Oyster	3.6	
	3	1992	*Corbicula*	1.3	
	3	1992	Oyster	3.5	

SOUTH BAY, cont'd	Ref	Date	Species	Se (ug/g dw)	Range (est. from wet weight)
Dumbarton Bridge	1	1/82	TCM	1.47	
	1	1/86	TCM	4.38	
	3	1991	TCM	1.2	
	3	1991	Oyster	3.3	
	3	1992	TCM	2.3	
Redwood Creek	2	1975	*Mya arenara*	8.4	
	2	1975	*Tapes japonica*	9.7	
	2	1975	TCM	6.8	
	2	1975	Oyster *	4.9	
	1	2/82	TCM	2.1	
	1	1/82	TCM	1.83	
	1	1/82	TCM	1.90	
	1	10/82	TCM	3.47	
	1	12/82	TCM	5.47	
	6	Fall 86	TCM		3.6-4.0
	6	Fall 86	TCM		3.6-4.0
	3	1991	TCM	2.3	
	3	1991	Oyster	3.5	
	3	1992	TCM	2.5	
San Mateo Bridge	2	4/75	*Mya arenara*	8.4	
	2	4/75	*Tapes japonica*	9.9	
	2	4/75	TCM	3.7	
	2	4/75	TCM	3.9	
	2	4/75	*Ostrea lurida*	4.2	
	1	1/82	TCM	2.1	
	1	1/82	TCM	2.1	
	1	1/86	TCM	3.77	
Coyote Point	2	4/75	*Mya arenara*	2.7	
	2	4/75	*Tapes japonica*	5.8	
	2	4/75	TCM	3.4	

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SOUTH BAY, cont'd	Ref	Date	Species	Se (ug/g dw)	Range (est. from wet weight)
Coyote Point, cont'd	2	4/75	TCM	6.5	
	2	4/75	*Ostrea lurida*	4.5	
Bayview Park/ Hunters Point	2	4/75	*Mya arenara*	2.7	
	2	4/75	*Tapes japonica*	4.5	
	2	4/75	TCM	3.5	
	2	4/75	*Ostrea lurida*	4.5	
	1	1/82	TCM	2.6	
Islais Creek	2	4/75	TCM	7.9	
Hayward Outfall	6	Fall 86	TCM		4.3-4.7
	6	Fall 86	TCM		4.9-5.3

CENTRAL and SAN PABLO BAYS	Ref	Date	Species	Se (ug/g dw)	Range (est. from wet weight)
Treasure Island	1	2/82	TCM	2.77	
	1	1/86	TCM	4.43	
	1	1/87	TCM	5.31	
	3	1991	TCM	3.0	
	3	1991	Oyster	3.5	
	3	1992	TCM	3.2	
Albany	2	4/75	*Mya arenara*	4.1	
	2	4/75	*Tapes japonica*	5.2	
	2	4/75	TCM	4.9	
	2	4/75	TCM	4.5	
	2	4/75	*Ostrea lurida*	4.5	
Richmond Harbor	1	2/82	TCM	3.0	
Richmond Bridge	1	2/82	TCM	6.8	
Pt. San Pablo	6	Fall 86	TCM		5.1-5.5

CENTRAL and SAN PABLO BAYS, cont'd	Ref	Date	Species	Se (ug/g dw)	Range (est. from wet weight)
Pt. San Pablo, cont'd	6	Fall 86	TCM		4.7-5.1
Castro Cove	6	Fall 86	TCM		5.3-5.7
	6	Fall 86	TCM		7.9-8.3
	6	Fall 86	TCM		16.8-17.2
	6	Fall 86	TCM		17.6-18.0
	5	11/87	*Musculus senhousia* (incl. shell)	1.4	
	5	11/87	*Tapes japonica* (incl. shell)	0.54	
	5	2/88	*Tapes japonica* (incl. shell)	0.52	
Point Pinole	2	4/75	*Mya arenara*	7.4	
	2	4/75	*Ischadium demissum*	6.9	
	1	2/82	TCM	2.7	
	1	1/86	TCM	2.26	
	6	Fall 86	TCM		3.2-3.6
	1	1/87	TCM	4.54	
	3	1991	TCM	2.6	
	3	1991	Oyster	2.7	
	3	1992	TCM	3.4	
Wilson Point	5	11/87	*Musculus senhousia* (incl. shell)	0.65	
Bennett's Marina	6	Fall 86	TCM		4.2-4.6
Davis Point	1	12/82	TCM	3.73	
	3	1991	Oyster	3.6	
	3	1992	Oyster	2.5	
Unocal	6	Fall 86	TCM		5.3-5.7

CENTRAL and SAN PABLO BAYS, cont'd	Ref	Date	Species	Se (ug/g dw)	Range (est. from wet weight)
Unocal, cont'd	6	Fall 86	TCM		13.2-13.6
	6	Fall 86	TCM		7.4-7.8
Mare Island	1	11/85	TCM	3.71	
		1/87	TCM	4.40	
Petaluma River Entrance	5	11/87	*Potamo-corbula* (incl. shell)	1.2	
	5	2/88	*Potamo-corbula* (incl. shell)	1.3	
China Camp	5	11/87	*Musculus senhousia* (incl. shell)	2.3	

CARQUINEZ STRAIT	Ref	Date	Species	Se (ug/g dw)	Range (est. from wet weight)
Exxon	6	Jan 87	Oyster		4-10
	6	Jan 87	Oyster		5-11
Shell	4	1985-86	*Corbicula*	3.9	
	6	Jan 87	Oyster		13-19
Benecia-Martinez Bridge	4	1/85-9/86	TCM	3.9	
	6	Fall 86	TCM		1.3-1.8
	6	Jan 87	Oyster		9.15
High Voltage Platforms	6	Jan 87	Oyster		5-11
Avon Pier (Tosco)	4	1985-86	*Corbicula*	5.2	
	6	Jan 87	Oyster		7-13
	6	Jan 87	Oyster		6-12

SUISUN BAY	Ref	Date	Species	Se (ug/g dw)	Range (est. from wet weight)
Channel Marker 11	6	1/87	Oyster		5-11
Roe Island	4	1985-86	*Corbicula*	3.9	
	4	1985-86	*Corbicula*	4.9	
	6	4/87	*Corbicula*	4.8	
	5	10/87	*Corbicula*	6.4	
	5	12/87	*Corbicula*	5.6	
		2/88	*Corbicula*	5.7	
		10/87	*Potamocorbula* (incl. shell)	1.0	
		12/87	*Potamocorbula* (incl. shell)	0.91	
		2/88	*Potamocorbula* (incl. shell)	1.2	
Middle Ground	6	1/87	*Corbicula*	3.6	
	6	2/85	*Corbicula*	4.4	
	6	4/87	*Corbicula*	4.5	
NY Slough	4	1985-86	*Corbicula*	4.0	
	1	1989	*Corbicula*	5.6	
Sherman Island	4	1985-86	*Corbicula*	4.4	
	3	1991	*Corbicula*	3.0	
Simpson Paper Mill	1	1989	*Corbicula*	5.4	
Honker Bay	4	1985-86	*Corbicula*	4.3	
	1	1989	*Corbicula*	6.1	
Grizzly Bay	1	1989	*Corbicula*	5.8	
Suisin Slough	6	1/87	*Corbicula*	4.9	
	1	1989	*Corbicula*	5.4	

Table Notes:

Range was given for wet weight to dry weight conversion for those data not reported in dry weight terms based on the following conversions: Resident/ transplant California mussels (mean 19% dw, std. dev. 2%, N=46, State Mussel Watch samples 1977-87), *Corbicula* (mean 12 % dw , std. dev. 4%, N=40, SMW 1977-87 data), Oysters (mean 11%

dw, std. dev 3%, N=11, Stephenson report).

References:
(1) CA State Mussel Watch data, 1977-87, preliminary 1989-90 data.
(2) Girvin et al., 1975.
(3) Stephenson, 1993.
(4) Johns et al., 1988.
(5) 1987-88 Se verification studies, (CDFG, 1988).
(6) 1986-87 Se verification studies, (CDFG, 1989).

The reference cited as Jenkins, Sanders, and Associates, 1992 in comment letters was not available for review.