# An Assessment of The Loading of Toxic Contaminants to The San Francisco-Bay Delta:

## Executive Summary

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# EXECUTIVE SUMMARY

## INTRODUCTION

The Aquatic Habitat Institute is required under the terms of contracts with the Environmental Protection Agency and the State Water Resources Control Board to review available data on the sources of toxic contaminants (trace elements, chlorinated hydrocarbons, and petroleum-derived hydrocarbons) to the San Francisco Bay-Delta. This report has been prepared in response to such a requirement.

The San Francisco Bay-Delta is a large and complex estuary, draining a significant proportion of the land area of California. As a result, the calculation of contaminant loading to the estuary is a complex task. The available data on toxicant concentrations and flows to the Bay-Delta vary in quality with respect to their usefulness in calculating contaminant loadings. In many cases, assumptions are required in computing mass emissions, or data from estuaries elsewhere must be employed due to the lack of reliable local information. In such instances, the calculations and assumptions employed are clearly enumerated in the report, such that improved loading estimates may be easily computed at a future time, when more reliable local data are available.

Contaminant loads to the estuary are derived from a number of distinct sources. These are dealt with individually in the main report; the method of calculation of

loadings is described briefly below. It is notable here that decisions were required at the commencement of the project on whether to attempt to provide a historical perspective to loadings, or to focus efforts on identifying current time-averaged loadings of contaminants as accurately as possible. It was argued that the more recent data were generally more abundant and of higher quality with respect to analytical accuracy and precision, and to quality assurance and control. In addition, difficulties were faced with the previous historical estimates of contaminant loadings to the Bay-Delta, in that the data sources and assumptions used in their computation were often not stated. As a result of these concerns, it was agreed between the contracting parties that the present report should focus on more recent data (1984 to 1986 inclusive) and should attempt to define best estimates of current time-averaged loadings of contaminants to the Bay-Delta.

## CONTAMINANT SOURCES TO THE BAY-DELTA

**Point Sources:** Data employed in this report on toxicant loadings from point sources (publicly owned treatment works [POTWs] and industrial discharges) are mainly derived from self-monitoring required by permits issued under the National Pollution Discharge Elimination System (NPDES) program. This monitoring provides a substantive database for computing contaminant loads to the estuary from the major point source

discharges; as a result, the estimates of loadings from these sources are among the most precise. In general, three-year average loadings are employed to characterize each source. It was found that eight discharges generally dominate mass emissions of toxicants from POTWs to the estuary, and that POTWs as a whole provide the majority of loads of most trace metals to the estuary. Among industrial discharges, petroleum refineries contribute significant flows and amounts of certain contaminants to the Bay-Delta, including selenium, chromium, nickel, lead, copper, and zinc. Other large industrial concerns have generally less significant impacts on overall mass emissions of toxicants to the estuary, although the U.S. Steel plant in Pittsburg discharges large amounts of chromium, and the effluent from the Chevron Chemical facility in Richmond also contains high trace element concentrations on occasion. It is also notable that much less is known of the mass emissions of organic contaminants to the Bay-Delta from point sources than of trace metal loadings. This is largely due to analytical problems and inadequate quality control of analysis.

**Urban Runoff**: The local database required to calculate mass emissions of toxicants from urban runoff to the Bay-Delta is of very poor quality. Runoff volumes may be reasonably accurately predicted by employing estimates of urbanized land area, precipitation, and runoff coefficients. However, the

calculation of mass loads depends on a thorough knowledge of contaminant concentrations in runoff from these areas, and local information on this aspect is inadequate. Data from studies elsewhere have thus been employed to estimate probable loads to the Bay-Delta from this source. These estimates should be improved by the acquisition of reliable data on local runoff characteristics.

**Nonurban Runoff**: The calculation of contaminant loadings to the Bay-Delta from nonurban runoff in this report relies upon methods developed by the National Oceanic and Atmospheric Administration for this purpose. The basic technique involves the computation of trace element loadings through assessments of soil yield from nonurban land, coupled with estimates of average metal concentrations in soils. Mass emissions of chlorinated hydrocarbon pesticides are calculated in a different fashion, however, employing data on their rate of utilization in the Bay-Delta catchment and an assumed value for their release to the estuary in runoff. Estimates in this category in the present report are relevant only to the nonurban land draining directly to the Bay-Delta; loads in runoff derived from the Central Valley are incorporated in riverine inputs.

**Riverine Inputs**: The mass emissions of contaminants to the Bay-Delta in riverine inputs are calculated based on water quality and flow data for the major rivers entering the

Sacramento-San Joaquin Delta. The sites of sampling operationally define the upstream limit of the Bay-Delta (at Sacramento, Stockton, and Vernalis). Problems relating to infrequent sampling and analytical detection limits constrain the accuracy of these mass loading estimates. In particular, no loading data for organic contaminants from this source can be derived.

**Dredging and Dredged Material Disposal**: The remobilization and release of contaminants by dredging and dumping activities in the Bay-Delta do not truly represent de novo loads of contaminants, but are more a function of the redistribution of historically-introduced toxicants. However, this process may nevertheless give rise to elevated concentrations of contaminants in certain portions of the estuary, and is therefore considered here. While the theory relevant to toxicant remobilization during dredging and dredged material disposal operations is reasonably well-established, no reliable data exist to define the quantities or rates of contaminant release in such activities locally. Generic release rate estimates are therefore employed to provide an assessment of the possible impacts of this process on the overall abundance of contaminants in the Bay-Delta.

**Atmospheric Deposition**: The estimates of toxicant loading to the Bay-Delta through atmospheric deposition are calculated here only on the basis of the water surface area of the estuary (1240 $km^2$), as contaminants originally from the

atmosphere entering the estuary after their deposition on the surrounding land mass are accounted for in urban and nonurban runoff and in riverine inputs. As the local database is not adequate to permit estimation of contaminant loads from this source, information from the Great Lakes region (where extensive studies of this nature have been undertaken) is employed. There is a need for further investigations locally to refine these estimates.

**Spills**: Contrary to popular opinion, spills are generally found to be a relatively minor source of contaminants to estuaries, at least in the absence of single massive accidents. The available data on spills in the Bay-Delta are collected by the U.S. Coast Guard. This database is inadequate in two major respects. Firstly, little information is available on the precise contaminants spilled in an incident. Secondly, not all spills listed actually occurred; some were "potential spills" or were otherwise of an uncertain nature. The present synthesis employs the 1984-1986 data to derive generic estimates of loads of petroleum hydrocarbons to the Bay-Delta from this source.

**Hazardous Waste Sites**: No quantitative estimates of contaminant loadings from hazardous waste sites can be made, due to a paucity of data.

## MASS LOADING ESTIMATES

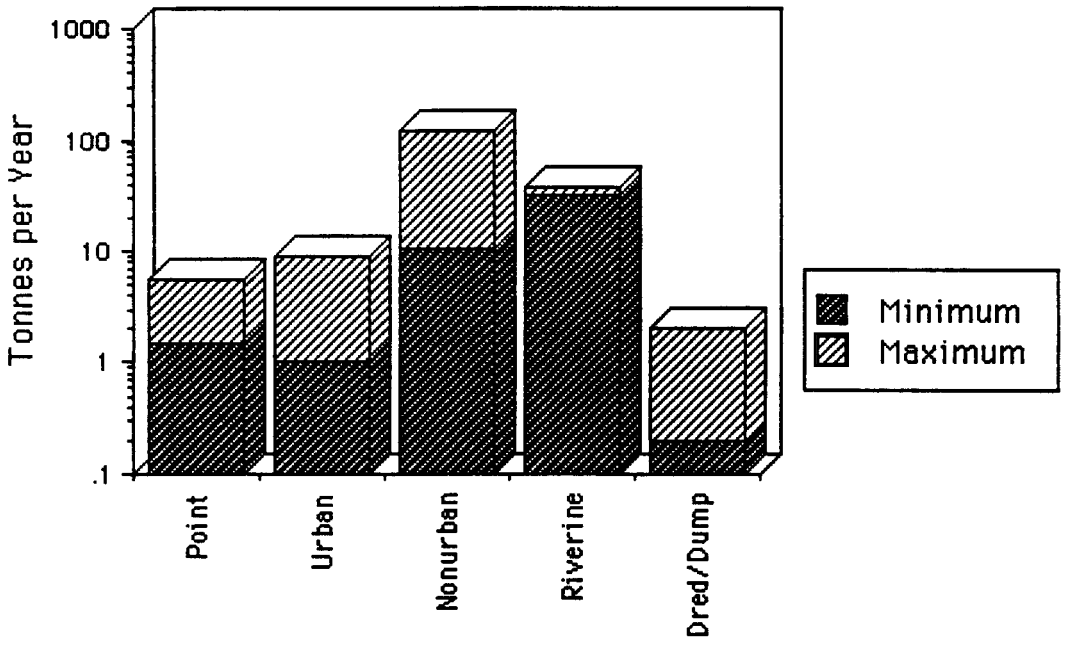
The marked uncertainties in loading estimates from each of the sources of contaminants considered in this report are significant, in that they emphasize the inadequacies inherent in the local database. Until monitoring of flows and (especially) contaminant concentrations in discharges entering the Bay-Delta is improved, mass loading estimates will continue to be uncertain. This situation is unsatisfactory, as the management of Bay-Delta water quality (and its impact on beneficial uses in the estuary) depends at least to some degree on an understanding of the sources of toxicants in the estuary.

The uncertainties inherent in present loading calculations also render conclusions as to precise absolute mass emissions scientifically indefensible. As a result, loadings of toxicants are presented here as ranges, rather than single absolute values. It is considered that the true loads are most likely to lie within the ranges between the probable minimum and possible maximum values reported for each contaminant and source.

In some instances, the paucity of data is so great that even a range in mass loading cannot be derived for particular sources and contaminants. It follows that the overall loads of some toxicants are better characterized than those of others.

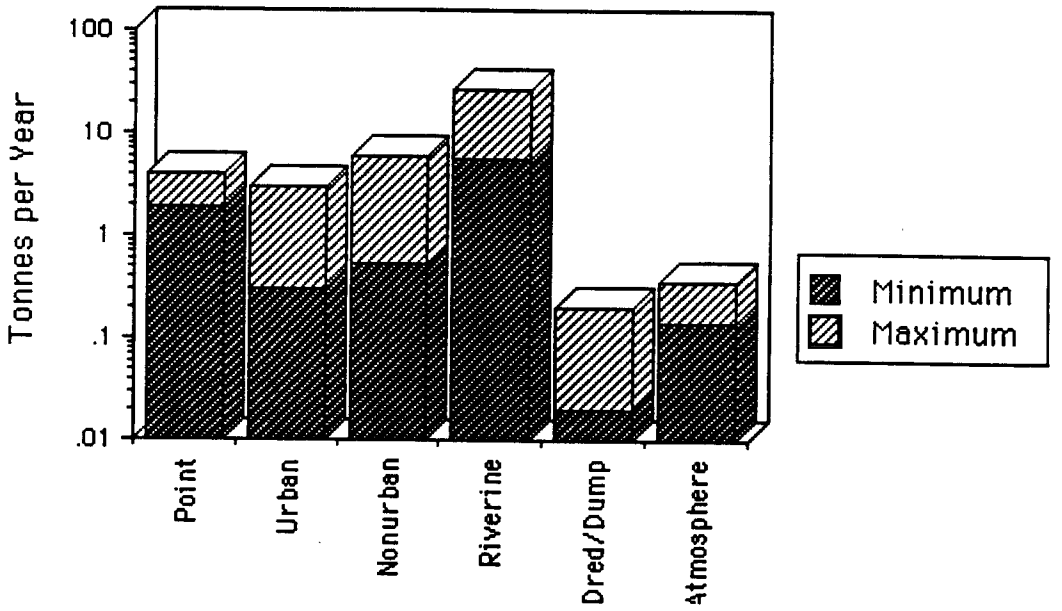
Estimated mass emissions of individual toxicants are presented in Figures ES1 to ES13, which are also shown in Section III of the main report. The relative ranking of sources for each contaminant is given in Table ES1. Detailed discussion of these data is presented in the main report for each toxicant; generic conclusions only are included in this summary. It is evident from Table ES1 that most trace elements are derived predominantly from riverine inputs and nonurban runoff. Point sources and urban runoff are generally more minor sources of metal loadings to the estuary, at least with the exception of lead (which is present at significant levels in urban runoff). Atmospheric sources and the release of trace elements from dredging and dredged material disposal operations are negligible in their contribution to overall trace element loadings to the Bay-Delta. The mass emissions of three elements (nickel, selenium, and silver) are computed only on the basis of three quantified sources, data for other sources being unavailable. In two of these three cases (selenium and silver), point sources provide significant proportions of overall loadings to the estuary. In the case of selenium, such loads largely arise from refineries, whereas silver is derived mainly from POTWs, particularly in the South Bay.

Atmospheric deposition is far more important as a source of organic contaminants to the Bay-Delta than as a source of trace elements. Large quantities of polychlorinated



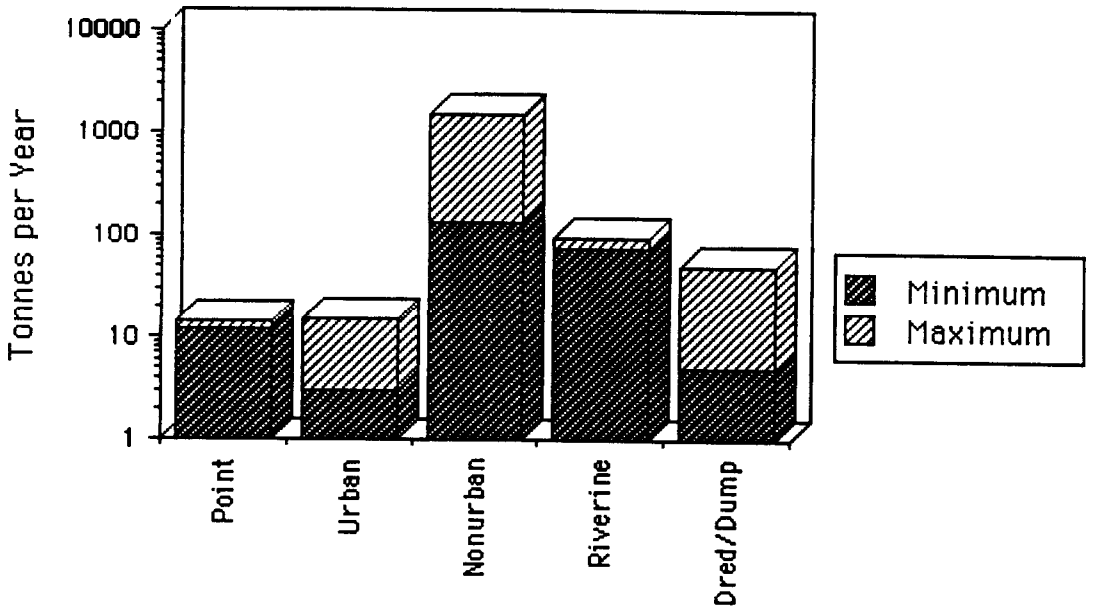

| | | | | | |
|---|---|---|---|---|---|
| Maximum | 5.7 | 9 | 119 | 37 | 2 |
| Minimum | 1.5 | 1 | 10.3 | 32 | 0.2 |

Fig. ES1. Estimated range for the mass loading of arsenic to the San Francisco Bay-Delta from point sources, urban runoff, nonurban runoff, riverine inputs, and dredging and dumping. All values in tonnes $yr^{-1}$.



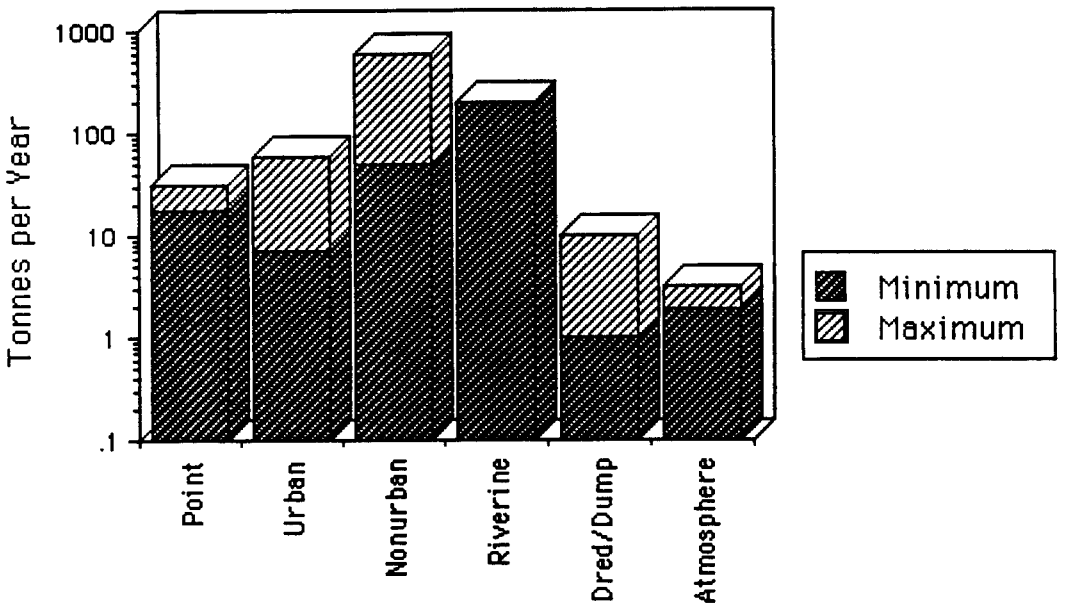

| | | | | | | |
|---|---|---|---|---|---|---|
| Maximum | 4.0 | 3 | 6 | 27 | 0.2 | 0.35 |
| Minimum | 1.9 | 0.3 | 0.52 | 5.5 | 0.02 | 0.14 |

Fig. ES2. Estimated range for the mass loading of cadmium to the San Francisco Bay-Delta from point sources, urban runoff, nonurban runoff, riverine inputs, dredging and dumping, and atmospheric deposition. All values in tonnes $yr^{-1}$.



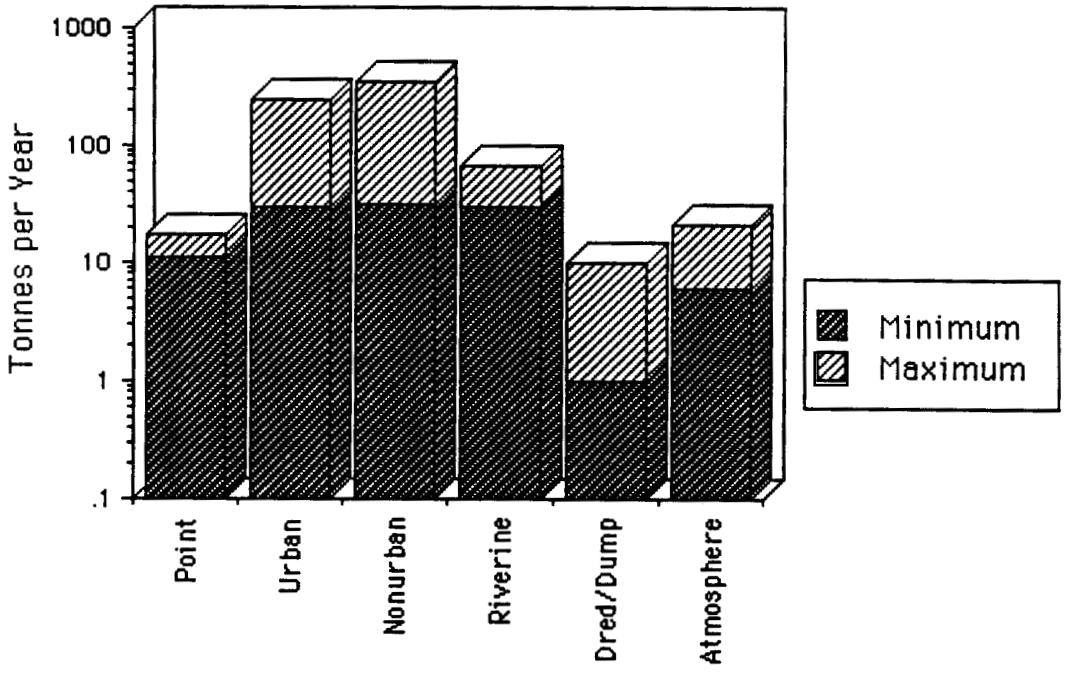

| | | | | | |
|---|---|---|---|---|---|
| Maximum | 14 | 15 | 1537 | 92 | 50 |
| Minimum | 12 | 3 | 134 | 77 | 5 |

Fig. ES3. Estimated range for the mass loading of chromium to the San Francisco Bay-Delta from point sources, urban runoff, nonurban runoff, riverine inputs, and dredging and dumping. All values in tonnes $yr^{-1}$.



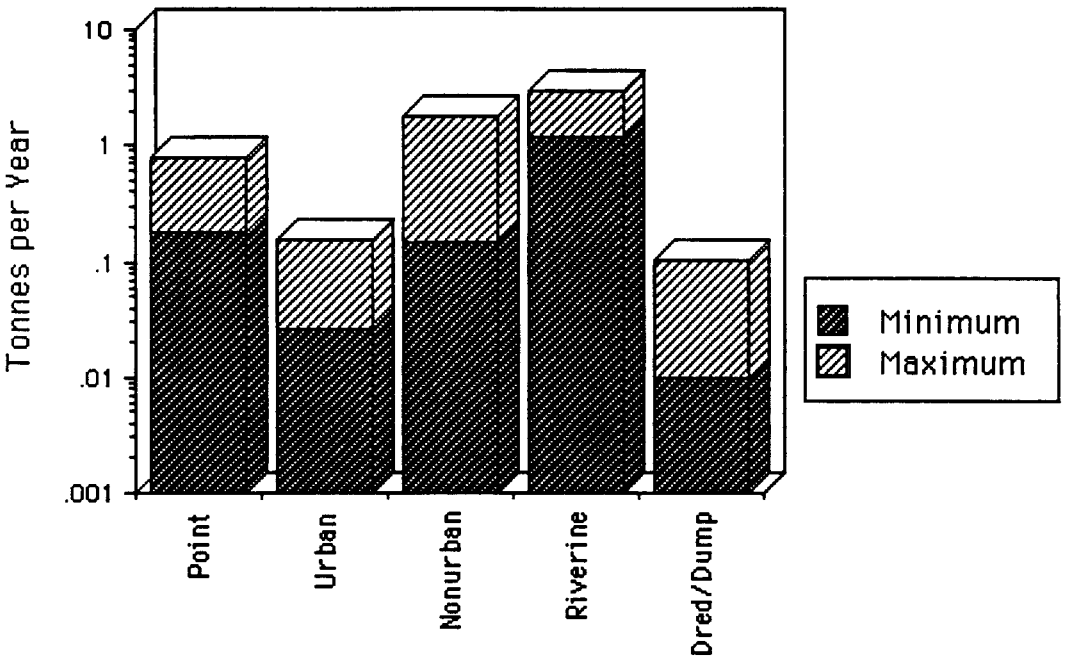

| | | | | | | |
|---|---|---|---|---|---|---|
| Maximum | 31 | 59 | 581 | 203 | 10 | 3.1 |
| Minimum | 18 | 7 | 51 | 203 | 1 | 1.9 |

Fig. ES4. Estimated range for the mass loading of copper to the San Francisco Bay-Delta from point sources, urban runoff, nonurban runoff, riverine inputs, dredging and dumping, and atmospheric deposition. All values in tonnes $yr^{-1}$.




| | | | | | | |
|---|---|---|---|---|---|---|
| Maximum | 17 | 250 | 358 | 66 | 10 | 21 |
| Minimum | 11 | 30 | 31 | 30 | 1 | 6 |

Fig. ES5. Estimated range for the mass loading of lead to the San Francisco Bay-Delta from point sources, urban runoff, nonurban runoff, riverine inputs, dredging and dumping, and atmospheric deposition. All values in tonnes $yr^{-1}$.

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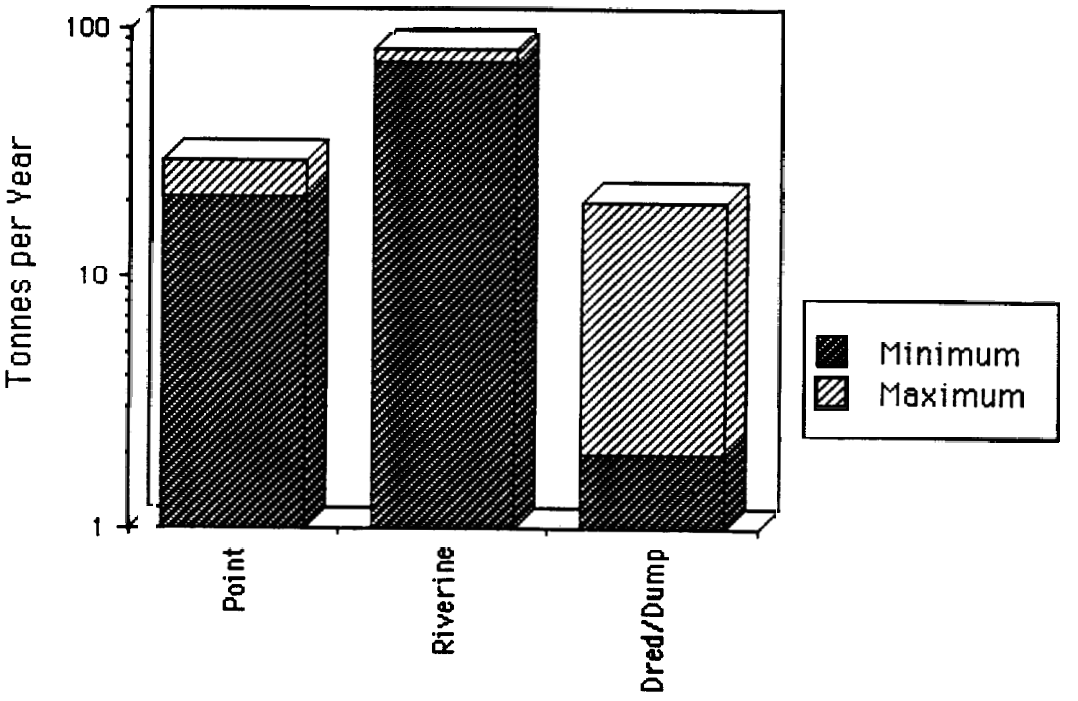
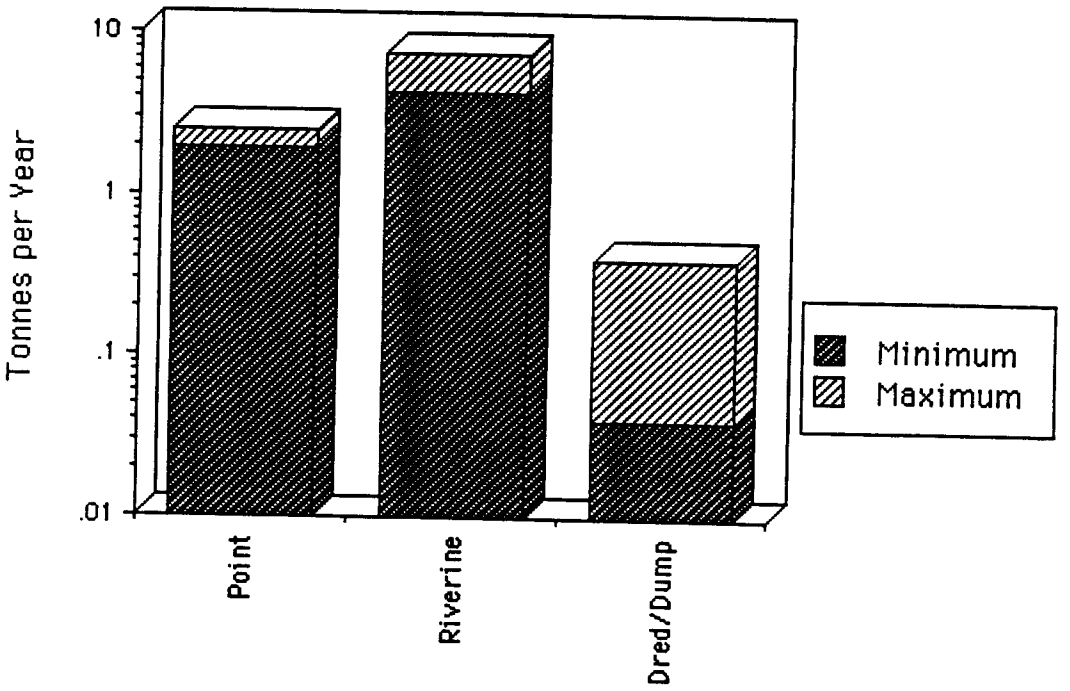
|---|---|---|---|---|---|
| Maximum | 0.8 | 0.15 | 1.7 | 3 | 0.1 |
| Minimum | 0.18 | 0.026 | 0.15 | 1.2 | 0.01 |

Fig. ES6. Estimated range for the mass loading of mercury to the San Francisco Bay-Delta from point sources, urban runoff, nonurban runoff, riverine inputs, and dredging and dumping. All values in tonnes $yr^{-1}$.



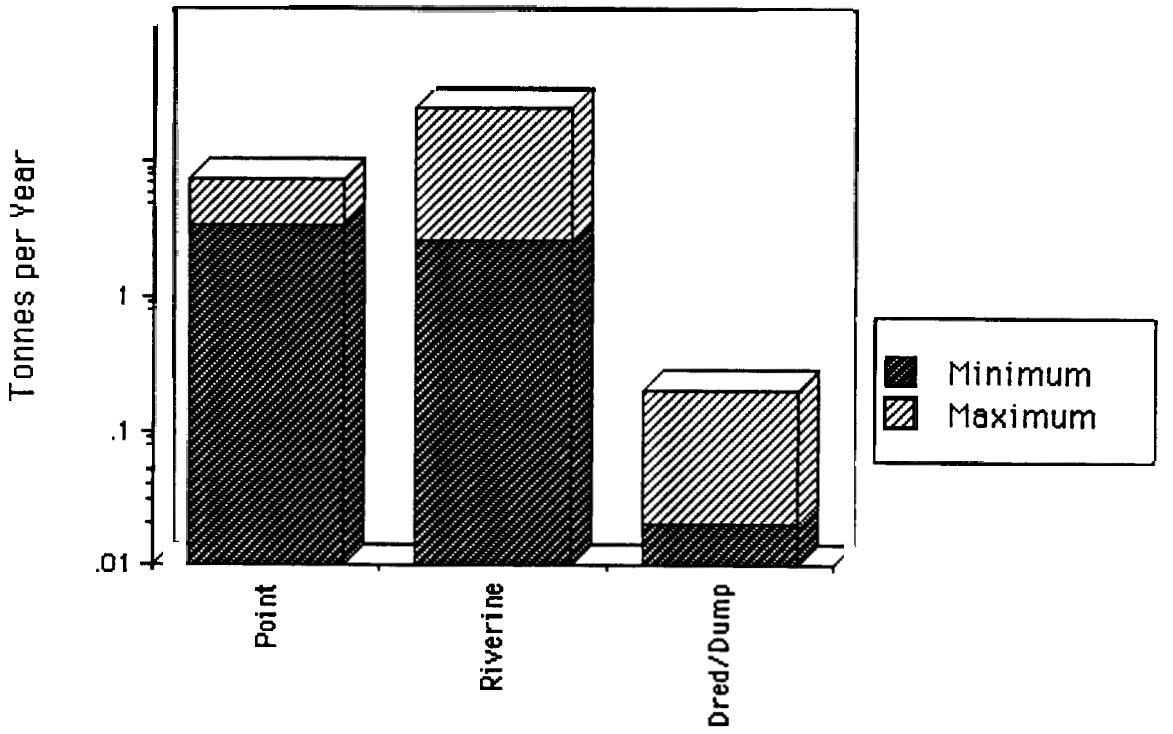

| | | | |
|---|---|---|---|
| Maximum | 29 | 82 | 20 |
| Minimum | 21 | 74 | 2 |

Fig. ES7. Estimated range for the mass loading of nickel to the San Francisco Bay-Delta from point sources, riverine inputs, and dredging and dumping. All values in tonnes $yr^{-1}$.




| | | | |
|---|---|---|---|
| Maximum | 2.5 | 7.4 | 0.4 |
| Minimum | 1.9 | 4.3 | 0.04 |

Fig. ES8. Estimated range for the mass loading of selenium to the San Francisco Bay-Delta from point sources, riverine inputs, and dredging and dumping. All values in tonnes $yr^{-1}$.

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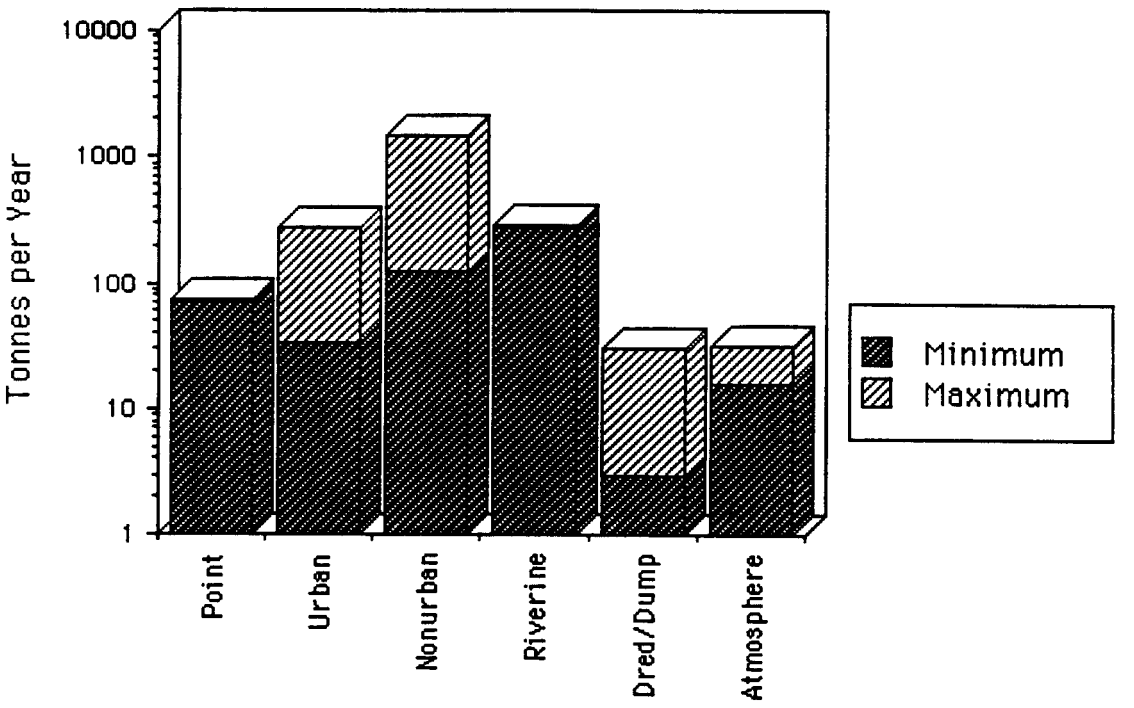
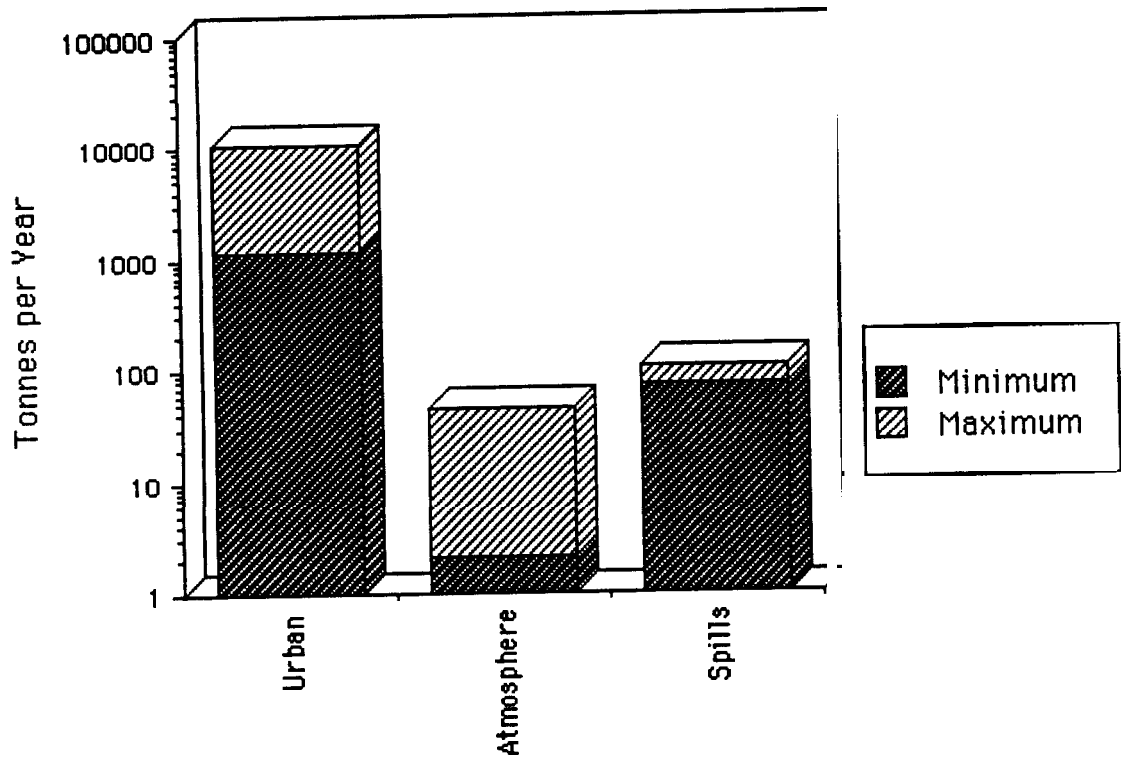
|---|---|---|---|
| Maximum | 7.5 | 26 | 0.2 |
| Minimum | 3.3 | 2.6 | 0.02 |

Fig. ES9. Estimated range for the mass loading of silver to the San Francisco Bay-Delta from point sources, riverine inputs, and dredging and dumping. All values in tonnes $yr^{-1}$.



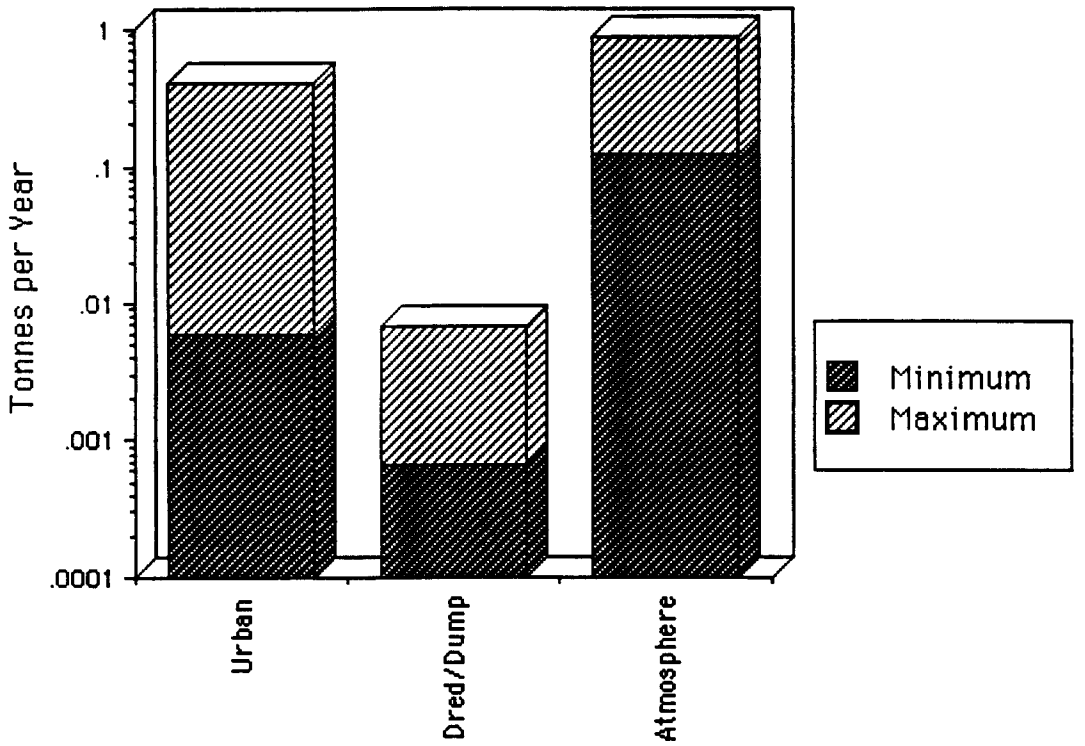

| | | | | | | |
|---|---|---|---|---|---|---|
| Maximum | 74 | 268 | 1453 | 288 | 30 | 32 |
| Minimum | 70 | 34 | 126 | 272 | 3 | 16 |

Fig. ES10. Estimated range for the mass loading of zinc to the San Francisco Bay-Delta from point sources, urban runoff, nonurban runoff, riverine inputs, dredging and dumping, and atmospheric deposition. All values in tonnes $yr^{-1}$.



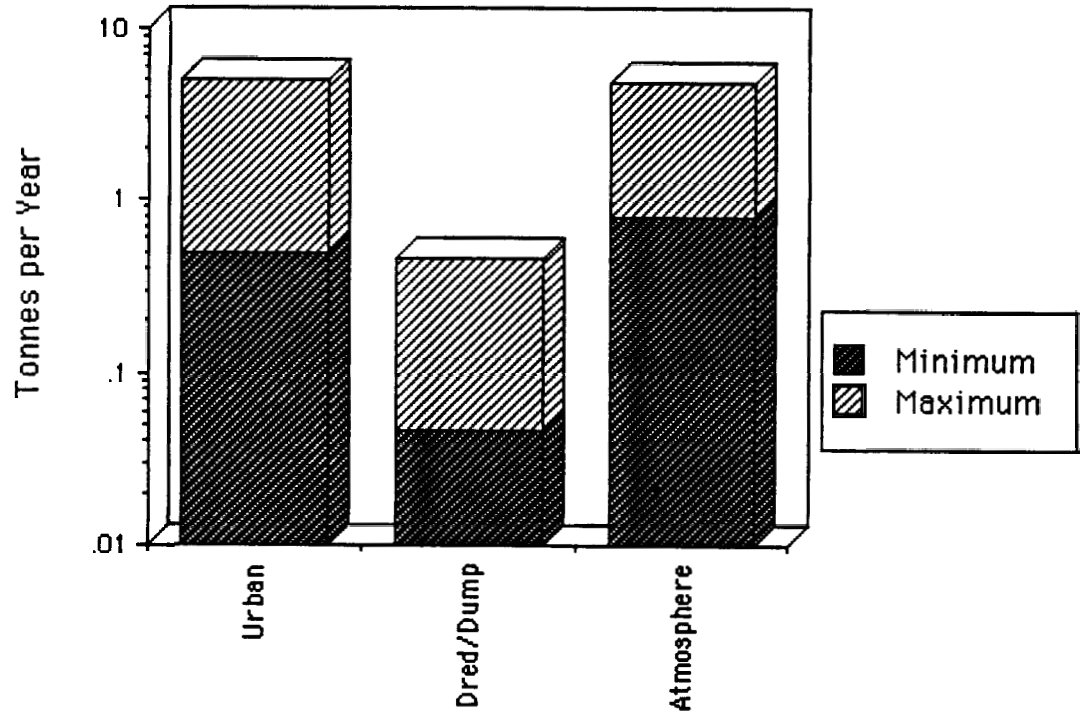

| | | | |
|---|---|---|---|
| Maximum | 11016 | 45 | 110 |
| Minimum | 1143 | 2.1 | 72 |

Fig. ES11. Estimated range for the mass loading of total hydrocarbons to the San Francisco Bay-Delta from urban runoff, atmospheric deposition, and spills. All values in tonnes $yr^{-1}$.




| | | | |
|---|---|---|---|
| Maximum | 0.4 | 0.0067 | 0.75 |
| Minimum | 0.006 | 0.00067 | 0.12 |

Fig. ES12. Estimated range for the mass loading of PCBs to the San Francisco Bay-Delta from urban runoff, dredging and dumping, and atmospheric deposition. All values in tonnes $yr^{-1}$.

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|---|---|---|---|
| Maximum | 5 | 0.47 | 4.8 |
| Minimum | 0.5 | 0.05 | 0.8 |

Fig. ES13. Estimated range for the mass loading of PAHs to the San Francisco Bay-Delta from urban runoff, dredging and dumping, and atmospheric deposition. All values in tonnes $yr^{-1}$.

TABLE ES1. Ranking of loading estimates for various contaminants and sources in the San Francisco Bay-Delta. Ranks for each contaminant are given based on minimum and maximum loading estimates, from greatest (1) to least.

| | | POINT SOURCES | URBAN RUNOFF | NONURBAN RUNOFF | RIVERINE INPUTS | DREDGING\DISPOSAL | ATMOSPHERE | SPILLS |
|---|---|---|---|---|---|---|---|---|
| ARSENIC | Minimum | 4 | 3 | 2 | 1 | 5 | - | - |
| | Maximum | 4 | 3 | 1 | 2 | 5 | - | - |
| CADMIUM | Minimum | 2 | 4 | 3 | 1 | 6 | 5 | - |
| | Maximum | 3 | 4 | 2 | 1 | 6 | 5 | - |
| CHROMIUM | Minimum | 3 | 5 | 1 | 2 | 4 | - | - |
| | Maximum | 5 | 4 | 1 | 2 | 3 | - | - |
| COPPER | Minimum | 3 | 4 | 2 | 1 | 6 | 5 | - |
| | Maximum | 4 | 3 | 1 | 2 | 5 | 6 | - |
| LEAD | Minimum | 4 | 2.5 | 1 | 2.5 | 6 | 5 | - |
| | Maximum | 5 | 2 | 1 | 3 | 6 | 4 | - |
| MERCURY | Minimum | 2 | 4 | 3 | 1 | 5 | - | - |
| | Maximum | 3 | 4 | 2 | 1 | 5 | - | - |
| NICKEL | Minimum | 2 | - | - | 1 | 3 | - | - |
| | Maximum | 2 | - | - | 1 | 3 | - | - |
| SELENIUM | Minimum | 2 | - | - | 1 | 3 | - | - |
| | Maximum | 2 | - | - | 1 | 3 | - | - |
| SILVER | Minimum | 1.5 | - | - | 1.5 | 3 | - | - |
| | Maximum | 2 | - | - | 1 | 3 | - | - |
| ZINC | Minimum | 3 | 4 | 2 | 1 | 6 | 5 | - |
| | Maximum | 4 | 3 | 1 | 2 | 6 | 5 | - |
| TOTAL HYDROCARBONS | Minimum | - | 1 | - | - | - | 3 | 2 |
| | Maximum | - | 1 | - | - | - | 3 | 2 |
| PCBs | Minimum | - | 2 | - | - | 3 | 1 | - |
| | Maximum | - | 2 | - | - | 3 | 1 | - |
| PAHs | Minimum | - | 2 | - | - | 3 | 1 | - |
| | Maximum | - | 1 | - | - | 3 | 2 | - |

biphenyls and polyaromatic hydrocarbons enter the estuary through this route; this is in keeping with the known propensity of such contaminants to be transported aerially. However, caution is required in the interpretation of such data, as the loadings from several sources have not been quantified as yet.

## CONCLUSIONS

Considerable uncertainty surrounds any estimates of the mass loading of contaminants to the Bay-Delta which may be derived using presently-available data. This is due to inadequate monitoring, imprecision of analysis, and many other factors.

In addition, it is important to note that contaminant loading to the estuary (and the flux of toxicants through estuarine components) is a dynamic phenomenon, and is not fully described by annually-averaged estimates. **For example,** runoff and riverine inputs will undoubtedly provide the majority of trace element loadings to the estuary in periods of heavy rainfall (particularly considering their time-averaged importance as sources of metals to the Bay-Delta, as outlined here). However, in dry seasons, point sources may be significant with respect to trace metal loadings. Similarly, the impact of both atmospheric deposition and urban runoff on hydrocarbon delivery to the estuary varies seasonally. Thus, the actual importance of each contaminant source may alter markedly with time and season. Only one of

the sources considered here (dredging and dredged material disposal) can be identified as a truly minor source of contaminants to the estuary under all conditions. Even in this case, it is possible that local impacts may occur if contaminants are fractionated into fine suspended material during dredging and disposal operations and preferentially deposited in particular parts of the Bay-Delta.

Further studies are clearly required to improve the present understanding of contaminant loads (and their fluxes) in the estuary. To be successful, such future investigations should be cognizant of both the inadequacies of the existing database and the reasons for such problems. It is to be hoped that the present report provides much data relevant to such matters, and will aid in future improvements.