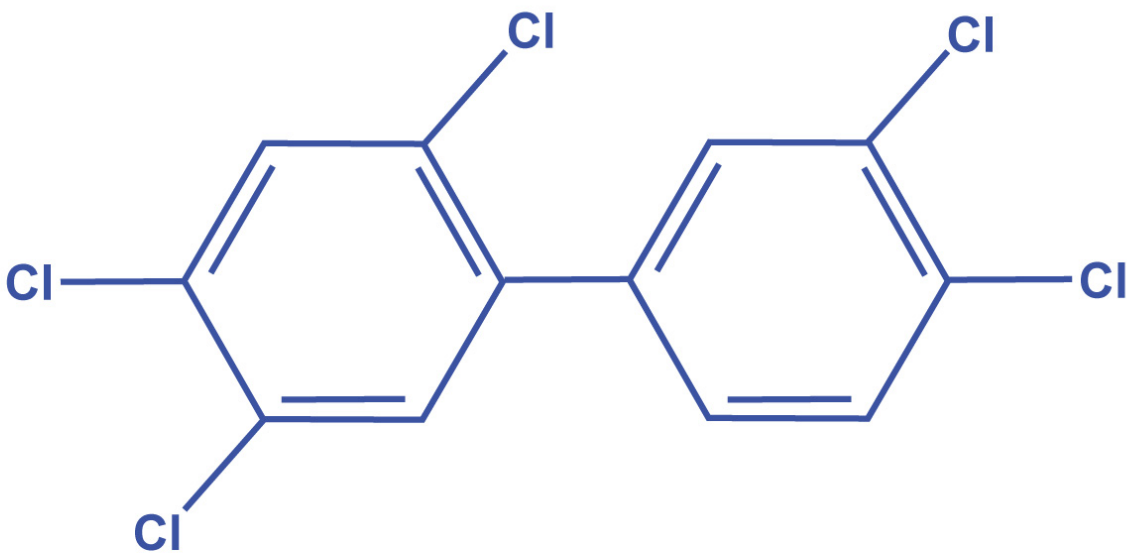
Results of Independent Testing of SFEI's Multibox Model for PCB Fate and Transport



2,3',4,4',5-PENTACHLOROBIPHENYL

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SUMMARY AND RECOMMENDATIONS

This work assignment, designed to independently test Version 2.0b of SFEI's Multibox model (MBM) for PCB transport in San Francisco Bay, has been completed. The period of performance was from April 2005 through August 2005. All tests that were conducted on MBM are described herein. A set of recommendations has been developed, and is provided below.

1. Subsequent to the February 2005 issuance of the draft report that describes Version 1 MBM model and its application to San Francisco Bay (Leatherbarrow et. al., 2005), a number of modeling-related activities have been undertaken:
    - The sediment transport model used in MBM has been updated.
    - Comments on the draft report and Version 1 of the MBM have been received by SFEI, some which were subsequently incorporated into the model.
    - Independent testing of the model has been completed.

    However, no new model documentation has been completed since the February 2005 draft report. It is recommended that a new report be developed that provides a update on the model and its algorithms, documents its application to San Francisco Bay, address responses to comments received on Version 1 model documentation, and provides responses to the finding of the model testing contained herein.
2. A review and modification of the input data sets used by MBM is recommended since some historical data sets are incomplete and should be populated. Additional variability should be added to the data sets in the forecast period.
3. Several of the equations in the draft report appear to be obviated with the new Version 2.0b of the model. Those equations should be removed from future documentation and replaced with the appropriate equations.
4. The possible impacts of sea level rise at the Golden Gate on PCB flushing from the Bay within the 21st century (the time frame of the forecast period) should be evaluated.
5. At some locations within San Francisco Bay (particularly in the Lower South Bay region) it appears that suspended solid concentrations in the lower layers of the model's boxes are consistently overestimated. It is recommended that an analysis of these effects on PCB transport be evaluated.
6. An evaluation of the effects of the spin-up period should be undertaken to determine if PCB transport was influenced during the hindcast and forecast period results and if those influences are artificial. If appropriate, alternatives for removing effects of the spin-up period should be evaluated and implemented.
7. A comparison of measured PCB data against model-predicted results illustrates that the model generally over-predicts the amount of PCBs in the Bay's water and sediment. One possible reason for this could be that the historical loading input to

the model was overestimated. This issue should be examined with the goal of generating model predictions that better match observations.

8. The conceptual model of PCB fate and transport in San Francisco Bay should be completed. This will help guide the approach to PCB modeling within the Bay. At present, only the congener PCB-118 is simulated. The appropriateness of simulating a single congener should be evaluated. Several modeling alternatives, consistent with the conceptual model or consistent with other accepted approaches, should be examined.

9. A number of other miscellaneous suggestions are provided throughout the report. They are:

    - Discuss why the two modeled PCB profiles for 1970 and 1990 differ as much as they do (see Figure 7).
    - Examine whether applying the UP equation for salinity prediction to prediction of total water column PCB prediction leads to any drift in the solution, given that some processes (such as volatilization) are added at the end of a time step.
    - Examine how model predicted sediment volume changes (examples shown in Table 6) are influenced by the model initialization conditions (spin-up period).
    - Examine ways to remove the necessity of scaling the sediment PCBs to initialize the forecast period by finding the basic cause(s) of the discrepancy between observed and predicted sediment PCB concentrations.

INTRODUCTION

Tetra Tech, Inc. has been tasked by the Clean Estuary Partnership (CEP) to review the multibox model for PCB fate and transport as applied to San Francisco Bay. This task began in April 2005 and was completed in August, 2005. During the course of this work, a PowerPoint presentation of major findings was completed and disseminated on July 28, 2005. That presentation included most of the same tests and results found here, but contained less explanatory text. Also, several comments on that presentation in the form of e-mails and a PowerPoint presentation were received and have been addressed herein. All of those comments are contained in the Attachments.

STUDY APPROACH

Independent testing was performed on Version 2.0b (V.2b) of the multibox model (abbreviated MBM in this review) that was completed in April 2005 by SFEI. Compared to Version 1 (V.1), V.2b contains a modified suspended solids/bed exchange module (called UPS in this review which is short for the module developers, Uncles/Peterson/ Schoellhamer), and other coding changes implemented as a result of review comments that SFEI received following the release of the V.1 draft report (Leatherbarrow et al., 2005). Since model V.2b has superceded model V.1, the results in Leatherbarrow et al. (2005) called the "draft report" subsequently in this review, have also been superceded, since the results in the draft report are based entirely on model V.1.

COMPONENTS AND LIMITS OF INDEPENDENT TESTING

A summary of the tasks completed during this review, as well as tasks that were beyond the scope of the project, are shown in Table 1. Testing consisted of both examining model results for plausibility, and examining certain specific lines of code for their correct functionality. The specific code examined focused on the PCB module of MBM.

Two other major MBM components (in addition to the PCB module) are the Uncles-Peterson (UP) model that predicts hydrodynamic variables (current velocities) and salinity (Uncles and Peterson 1995, 1996) and the UPS model (a reference to this model is not available at this time). The UP model has been used numerous times in the past, and the UPS model has recently been completed by the USGS. While the model code was not specifically checked for either of these two models, nevertheless some general comments have been generated that are provided in subsequent sections.

RESULTS OF MODEL TESTING

Model Compilation

The MBM was developed by scientists and engineers at SFEI using a Linux based operating system and not the more commonly available Windows operating system. Consequently, it was decided as a first step, to recompile MBM on a Windows PC. Should the model be freely distributed at some point in the future, it is likely that many of those users would have access to Windows and not Linux. Therefore this step, in addition to showing the model is working as anticipated, would have an added benefit of demonstrating that the model can be easily compiled on Windows-based PCs. Using a Visual Fortran compiler, MBM was successfully compiled on a Windows-based PC with little effort. All tests documented herein were performed using this compiled version.

Table 1
Components of and Limits to Independent Testing of V.2b of the MBM

Task Number	Components of Independent Testing
1	Recompile V.2b of MBM on Windows-based platform (SFEI used Linux-base platform).
2	Verify that MBM simulation results provided by SFEI for hindcast, forecast, and loading analyses are identical to results produced by Tt.
3	Examine input data sets used in hindcast and forecast for plausibility.
4	Develop and execute specific quantitative tests to check functionality of selected parts of code, and plausibility of predictions.
5	Evaluate specific issues that could influence predicted levels of PCBs in the Bay (such as using total PCBs and not examining subgroups).
6	Examine code structure to understand flow of information and to see if efficiencies can be gained for upcoming uncertainty work assignment.
7	Provide specific suggestions on all issues identified.
8	Document all results.

Number	Limits to Independent Testing
1	No code changes were made to MBM, except for diagnostic write statements.
2	No alternative data sets were assembled or tested.
3	Detailed analysis of the UP and UPS models was not done. Tests were conducted on both UP and UPS, but focus of most of the tests was on the PCB component of MBM.
4	There was no review of comments received by SFEI on their draft 2005 report.
5	Line-by-line verification of MBM was not done. Verification efforts were focused on PCB transport, and the equations that were presented in the draft 2005 report.

Model Comparisons to Simulations Previously Completed by SFEI

Prior to evaluating MBM, it was necessary that the reviewers were confident that the model was performing as expected. In order to do that, the reviewers requested and received the results of a number of simulations performed by SFEI on their Linux-based computer. Graphical comparisons were generated, and statistics of the differences were computed. The following summarizes those results.

Figure 1 shows the locations of each of the 50 boxes used by MBM (from Leatherbarrow et al. 2005). Many of the figures that follow show results by box number, so this figure is provided as a reference. Figure 2 compares dissolved PCB concentrations at three boxes (3, 19, and 37), both upper and lower layers, for forecast and hindcast periods. The results generated by the model developers are shown along the vertical axis, and the results by the reviewers are shown along the horizontal axis. The comparisons form a straight line with a 1:1 slope and no outliers, indicative that the results compare well. The root mean square (RMS) error between the two sets of results is in the neighborhood of six orders of magnitude less than the values themselves. Figure 3 compares particulate PCB concentrations (in the water column) for the same locations and simulation periods as in

Figure 2. Once again the comparisons fall along a 1:1 line with no outliers, and the RMS error is about six orders of magnitude below the concentrations themselves.

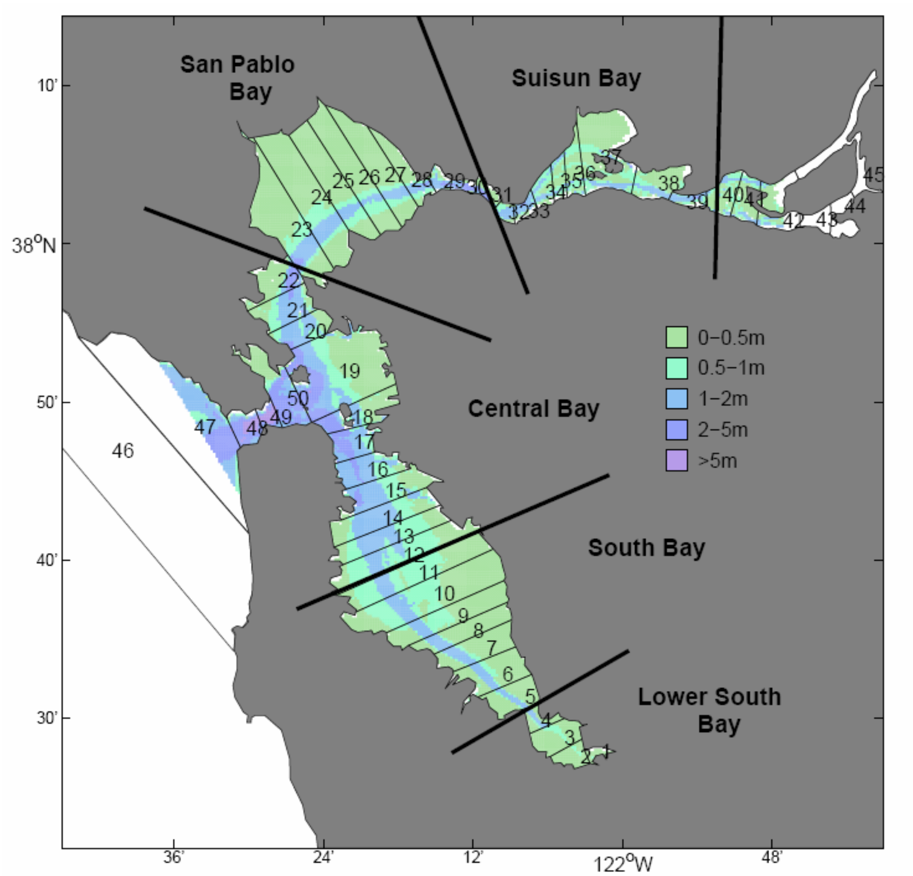


Figure 1. Location of 50 boxes that comprise the grid layout for the PCB Multibox model (from Leatherbarrow et al., 2005).

Because water column PCB concentrations match so well and PCB levels depend on all the other processes and data used by the model, it was anticipated that intermediate results, such as suspended solid concentration, would also match well. Figure 4 illustrates this. Once again, for the same locations and simulation periods as in the previous two figures, the comparisons are again along the 1:1 line with a small RMS error compared to the suspended solid concentration themselves. The final model comparisons were for PCBs in the surficial sediments. The results are for two sensitivity tests performed on PCB tributary loads, for loads twice the base case (Figure 5), and no tributary loads (Figure 6), at the same locations and simulation periods as for the earlier comparisons. The accuracy of comparisons is the same as above.

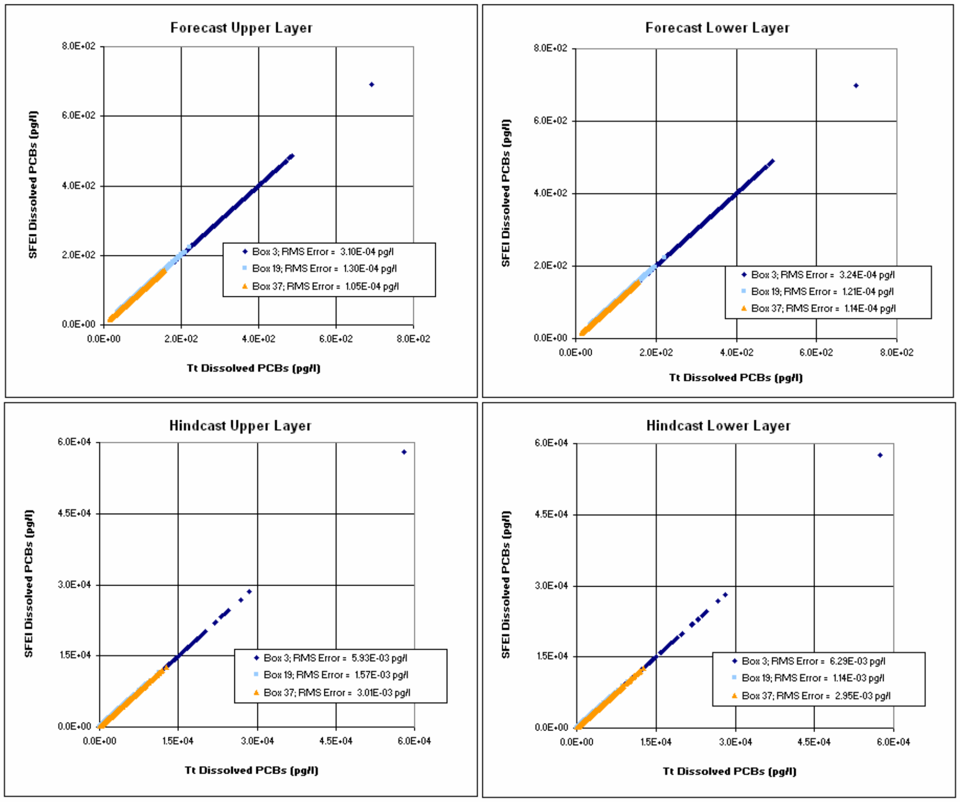


Figure 2. Comparison of dissolved PCB concentrations: model developers (SFEI) results vs. model reviewers (Tt) results.

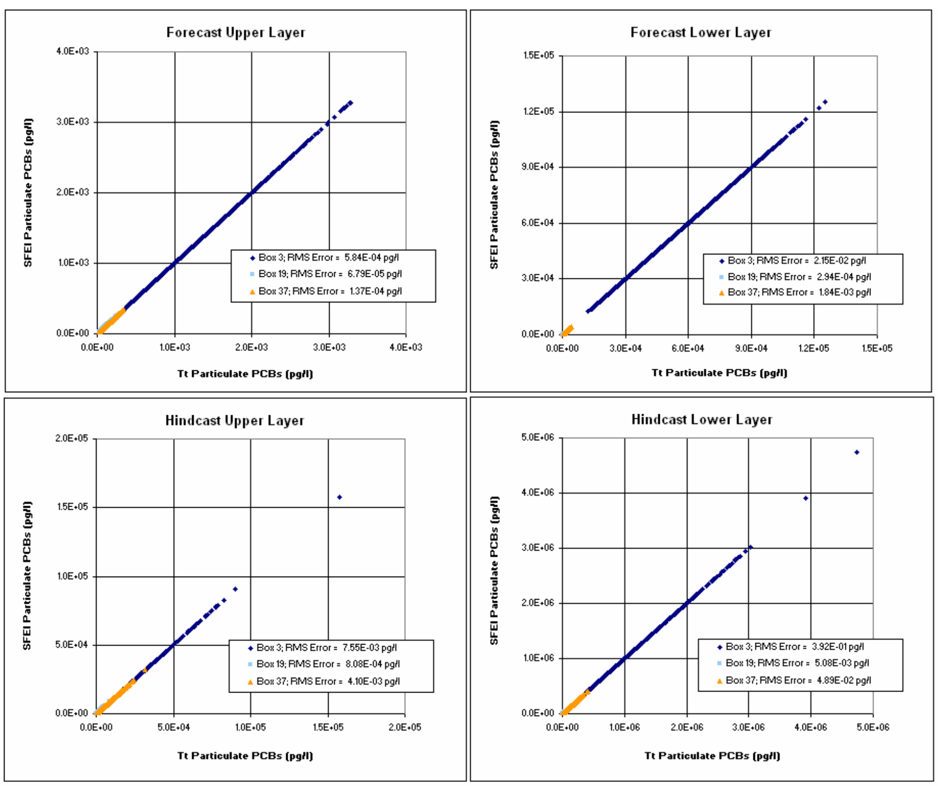


Figure 3. Comparison of particulate PCB concentrations: model developers (SFEI) results vs. model reviewers (Tt) results.

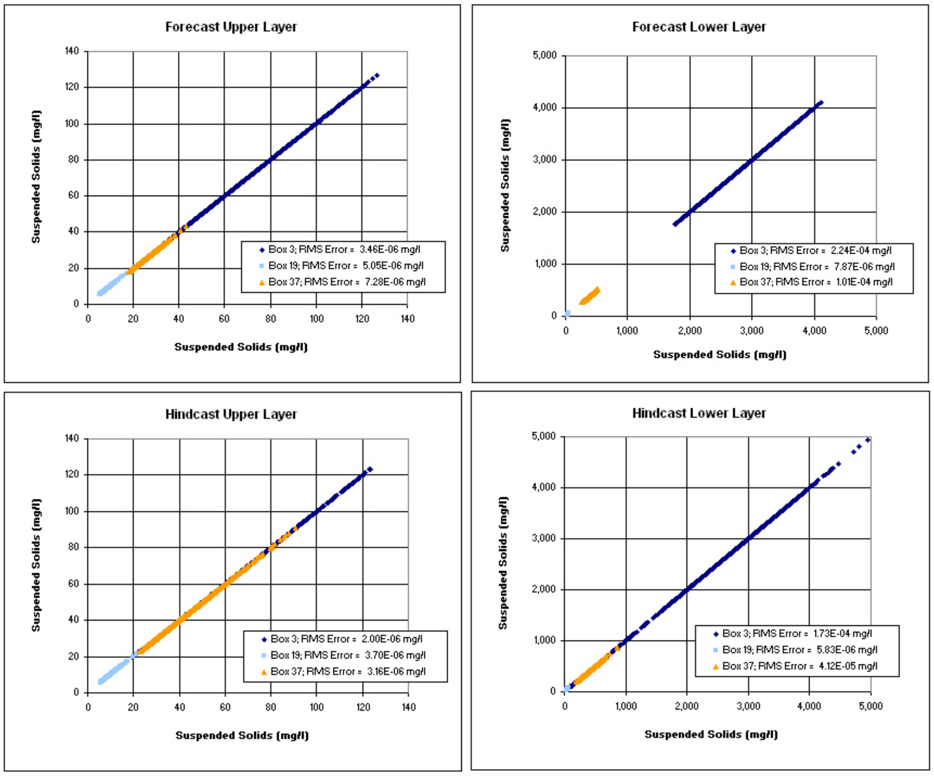


Figure 4. Comparison of suspended solids concentration predictions: model developers (SFEI) results vs. model reviewers (Tt) results.

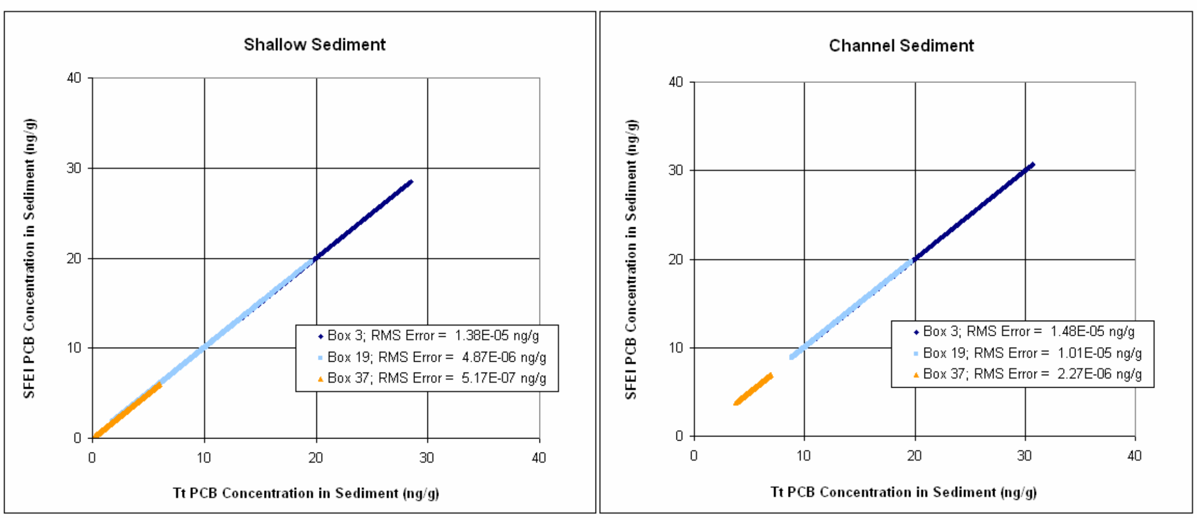


Figure 5. Comparison of PCB concentrations in sediments for 2X PCB tributary loads: model developers (SFEI) results vs. model reviewers (Tt) results.

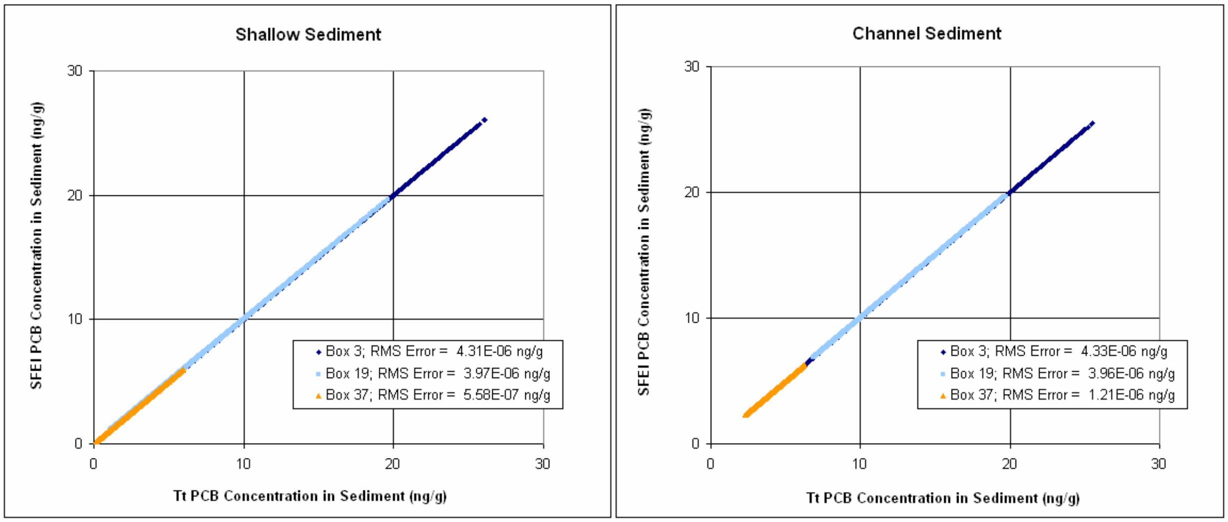


Figure 6. Comparison of PCB concentrations in sediments for no PCB tributary loads: model developers (SFEI) results vs. model reviewers (Tt) results.

Equation Checking

The set of 12 equations reported in Leatherbarrow et al. (2005) were examined for implementation in the code. Table 2 provides a general description of the equations. These equations that focus on PCBs are a subset of all the equations that comprise MBM.

Table 2.
Equations Reviewed for Code Verification Analysis

Equation	Description
#1	Salinity transport
#2	Sediment exchange with the bed
#3	Dissolved fraction of PCBs in water column
#4	Volatilization rate of PCBs
#5	Volatilization transfer coefficient for PCBs
#6	Liquid phase transfer coefficient for PCBs
#7	Vapor phase transfer coefficient for PCBs
#8	Schmidt number temperature dependency
#9	Dimensionless Henry's constant
#10	Temperature dependence on Henry's constant
#11-#12	Sediment PCB mixing

Equation 1: Salinity transport

This equation was originally implemented for the UP model, and has been adapted for PCB transport by sequentially adding terms (such as volatilization) at the end of the daily time step. Theoretically, all terms affecting the fate of PCBs in each media simulated should be solved simultaneously. It is not clear if the sequential nature of the solution introduces any drift in the simulation result, but it is suggested that some basic tests be performed to evaluate this potential effect.

Equation 2: Sediment Exchange with the Bed

This equation was originally presented in Lionberger (2003) for use in V.1 of UPS. It assumes that H, the layer thickness, is constant over time. For V.2b, this assumption is no longer made, so the equation should be replaced by the appropriate equations used in model V.2b. Since documentation of model V.2b of UPS is not presently available, the exact equations used are not known. It is suggested that the revised UPS equations replace Equation 2 in the next version of the MBM report.

Equation 3: Fraction of PCBs Dissolved in the Water Column

Equation 3, as it appeared in the draft V.1 report that was released in February 2005, was replaced in March 2005 by another equation that was coded in Model V.2b, possibly as a result of comments received during review of the draft report. The revised equation is:

$$\varphi_{ow} = \frac{1}{1 + SCC \bullet 10^{-6} \bullet oc \bullet K_{OC}}$$

Where

SSC = Suspended solid concentration, mg/L
oc = fraction organic carbon content of suspended solids, unitless
K_{oc} = organic carbon partition coefficient, L/kg

This equation correctly provides the ratio of the dissolved to total water column concentrations, assuming an equilibrium relationship exists between them. In the original V.2b code provided to the reviewers in April 2005, the conversion factor of 10^{-6} was missing. The error was found during the course of the testing (June 2005), corrected by SFEI, and all tests presented here were performed with the modified code.

Equations 4 and 5: Volatilization rate and transfer coefficient

The volatilization mass-transfer coefficient (V_e) shown in Equation 5 which has units of m/day is used to calculate the volatilization rate (k_v in Equation 4), which has units of 1/day. The equation for V_e is based on two-film theory, which has successfully been used for many years (for example, see Hornbuckle et al. 1994). The volatilization rate k_v

correctly reflects the fact that only the dissolved fraction of PCB in the upper layer volatilizes.

As a first check, hand-calculated values of V_e and k_v were generated using typical wind speeds over the Bay. Wind speed is one of the important variables that influences PCB volatilization. The hand-generated rates are:

- V_e = 0.37 m/day
- k_v = 0.012 /day

Typical values extracted from the model, over a range of simulated conditions, are:

- V_e = 0.053-0.66 m/day, box 3
- V_e = 0.025-0.60 m/day, box 37
- k_v = 0.00222-0.04 /day, box 3
- k_v = 0.00047-0.022 /day, box 37

The typical hand-generated values are within these ranges. A number of model-generated results were also replicated by hand, confirming that this section of the code is operating correctly.

Equations 6 to 8: Mass transfer coefficients for volatilization

Equations 6 through 8 provide the input functions for the two-film theory equations: V_{ew} for transfer across a thin liquid layer (Equation 6), V_{ea} for transfer across a thin air layer (Equation 7) , and a Schmidt number temperature correction (Equation 8). All equations are formulated consistently with Hornbuckle et al. (1994). Typical values were calculated externally to the model, again using typical wind speed data, and the following values resulted:

- V_{ew} = 0.75 m/day
- V_{ea} = 423 m/day
- Sc (at 15 °C) = 840.5

Example results extracted from the model were:

- V_{ew} = 0.031-4.1 m/day, boxes 3 and 37
- V_{ea} = 146-979 m/day, boxes 3 and 37
- Sc = 840.5

The externally generated results fall within these ranges. Also, several specific model-generated results were replicated by hand, a confirmation that this section of the code is operating correctly.

Equations 9 and 10: Henry's Law Constants

These two equations predict the dimensionless form of Henry's Law constant from the dimensional form, and the temperature dependency of Henry's Law Constant. They are the same equations used previously by other investigators, such as Hornbuckle et al. (1994). The temperature dependency predicts a doubling of Henry's Law constant for every 10 °C increase, which is a typical temperature dependency. The model-input Henry's Law constant that corresponds to a temperature of 25 °C was appropriately adjusted to the temperature of the Bay's water (15 °C) by the model.

Equations 11 and 12: PCB Mixing in Sediments

The sediment mixing equation (Equation 11 in the draft V.1 report) uses an equivalent vertical diffusion equation, along with depth dependent PCB decay. The vertical diffusion coefficient $D_b(z)$ has been formulated to exponentially decrease with depth:

$$D_b(z) = D_b(0)\exp\left(-z^2/(2\gamma^2)\right)$$

where:

D_{bo} = 71 cm^2/yr
γ = 9 cm

The boundary conditions used to solve Equation (11) are not provided in the draft V.1 report, and it is suggested they be presented and discussed in the next version of the report.

An examination of this equation showed that it reproduced the prescribed behavior such that:

$$D_b\,(z = 33\text{ cm}) = 0.001 D_b\,(z = 0)$$

While this equation was not rigorously verified, units were checked and found to be consistent throughout. As an additional check, several time-variable depth profiles of PCBs in the sediments were plotted and visually evaluated. An example for San Pablo Bay is shown in Figure 7. Focusing on the 1970 and 1990 channel profiles, it appears that those two sediment profiles differ significantly over depth, considering that they represent predictions that are only 20 years apart. An explanation of whether these differences are plausible should be provided.

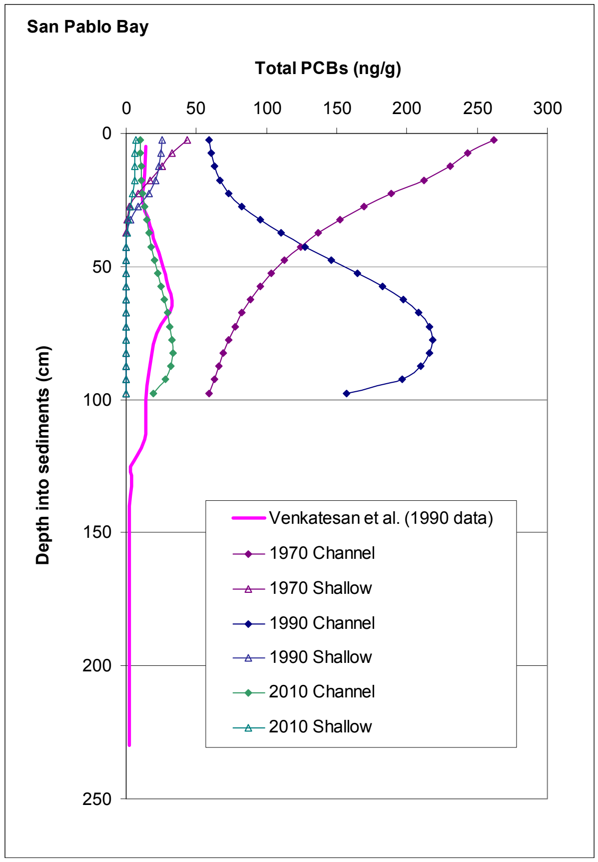


Figure 7. Total PCB concentrations versus depth in sediments in San Pablo Bay.

Examination of Input Data

Much of the input data time series required by MBM to simulate the hindcast and forecast periods were not presented in the draft V.1 report. They are therefore reviewed here, and consist of:

- Precipitation
- Delta flow rates
- Suspended solids concentrations
- Tides
- Ocean salinity
- Evaporation
- Wind

Before showing the data, two major findings are summarized:

- Some of the historical data sets (1940-2000) are not complete; that is, some of the data are missing. It is suggested that the time series be completed with appropriate historical data.

- The forecast data are largely based on 30-year climatological data, with some small variability added. Therefore, the data forecast period (2000- 2100) exhibits less variability than the historical data. It is suggested that approaches to add variability to the forecast data be examined, and alternate data sets for the forecasting period be generated and used. One of the specific reasons for suggesting that more variability be added to the forecast conditions is to ultimately add variability to predicted PCB concentrations within the Bay, and to more realistically simulate the recovery period.

Figures 8 and 9 show the time series of hindcast (in pink) and forecast (in blue) of precipitation and Delta flow rates used by MBM. These two graphs illustrate the two points mentioned above. Knowles and Cayan (2002) provide one option to add variability back to forecast precipitation and Delta flow rates. It is suggested that this method be reviewed and evaluated for suitability to the present work.

The MBM model developers chose to use climatological averages for future precipitation because of the uncertainty in how precipitation will change in California over the 21st century. Depending on which General Circulation Model (GCM) is used to make predictions and which greenhouse gas emissions scenario is simulated, GCMs predict quite different 21st century precipitation patterns and amounts in California. Some predictions show increasing precipitation, while others show decreasing amounts of precipitation (Hayhoe et al. 2004). Thus, assuming that the total annual rainfall will remain at historical levels is a reasonable assumption. Knowles and Cayan (2002) use this assumption in their analysis of projected 21st century Delta flow rates.

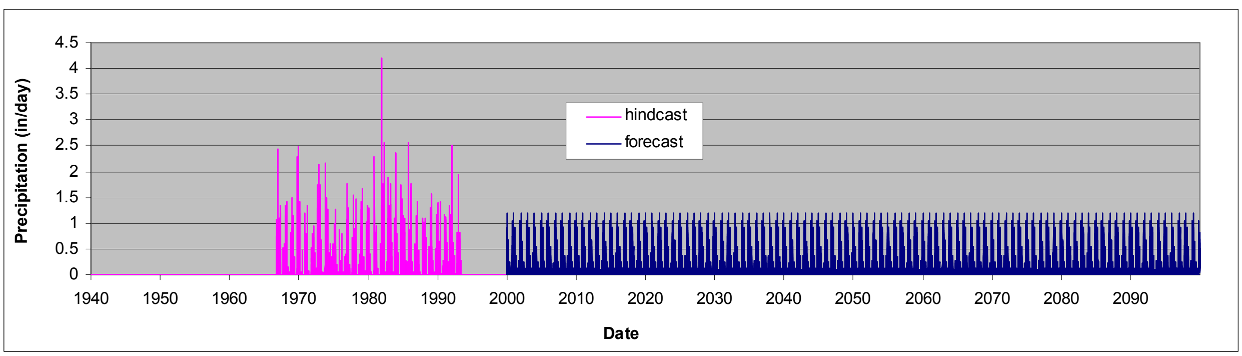


Figure 8. Time series of hindcast and forecast precipitation used by MBM.

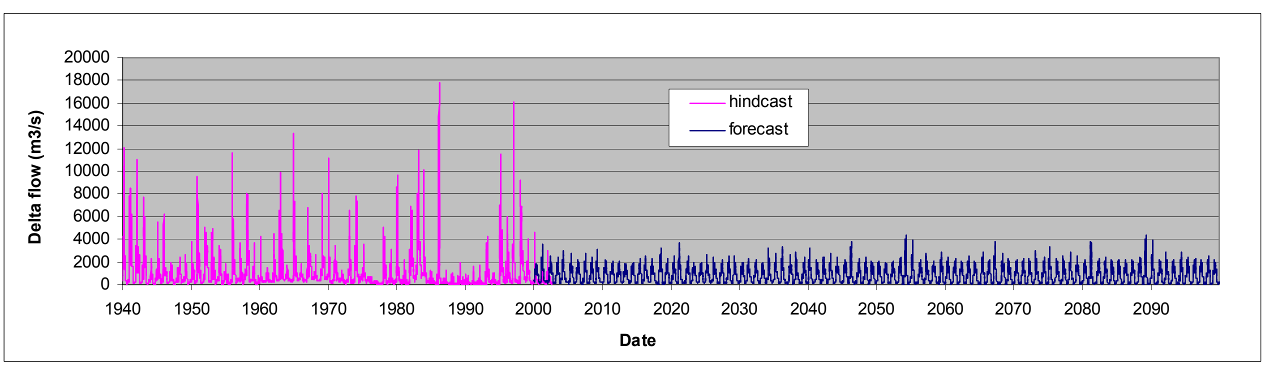


Figure 9. Time series of hindcast and forecast delta flow rates used by MBM.

The hindcast and forecast suspended solids data at Freeport are shown in Figure 10. The suspended solids concentrations have close to the same mean values, as expected, but the variability in the forecast data series is lower (see Table 3).

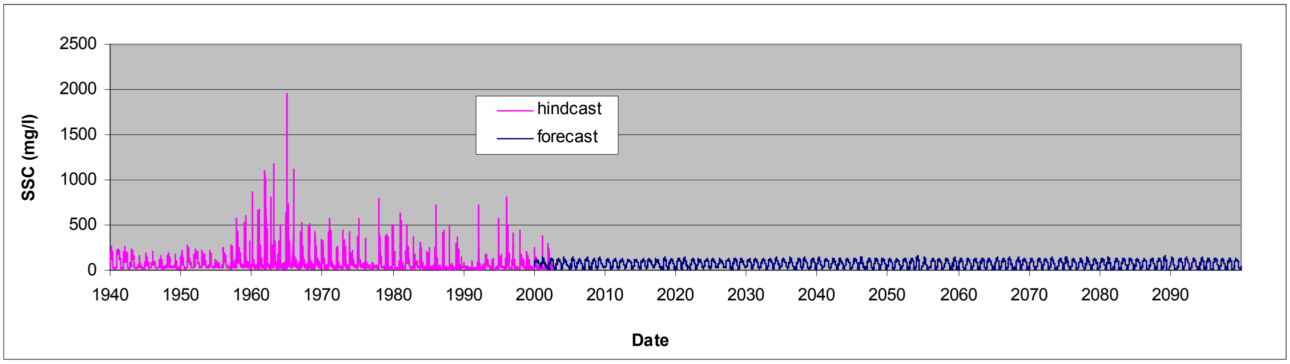


Figure 10. Time series of hindcast and forecast suspended solids concentrations at Freeport used by MBM.

Table 3
Statistics of Delta Flow and Freeport Suspended Solids Concentration Data Used by MBM

Delta Flow (m3/s)	Hindcast	Forecast
Minimum	0	0
Average	846	793
Maximum	17825	4391
Standard Deviation	1250	664

SSC (mg/l)	Hindcast	Forecast
Minimum	2	0
Average	63	71
Maximum	1960	158
Standard Deviation	71	42

Note: The 30 year climatological flow rate from 1971-2000 is about 810 m^3/s, close to both the hindcast and forecast average flow rates shown above.

Figure 11 shows the time series of hindcast and forecast evaporation rates from the Bay. Two anomalous conditions are illustrated: the 30-year period of missing data early in the hindcast, and the small but apparent shift in evaporation rate at the interface of the hindcast and forecast periods. Both of these issues should be addressed. Additionally, recent studies have shown that the state will warm over the 21st century due to increasing greenhouse gas concentrations (Knowles and Cayan 2002; Hayhoe et al. 2004). Ultimately the increased surface temperatures could lead to increased water temperatures, which could affect evaporation of Bay water, which in turn could influence circulation in parts of the Bay where residence times are large, such as Lower South San Francisco Bay. Figure 12 illustrates the possible influence of increased water temperatures on evaporation. For water temperature increases in the range of 1 ˚C to 5 ˚C, evaporation losses can increase by 5 percent to 40 percent.

The tidal state (TS) time series for the hindcast and forecast periods is shown in Figure 13. TS is used as input to the UP model (Uncles and Peterson 1995, 1996) that calculates salinity distribution throughout the estuary. TS is a dimensionless parameter whose magnitude varies by tidal amplitude. At the Golden Gate, de-trended water level data are used to calculate TS (Uncles and Peterson 1996) and it does not appear that the effects of future sea levels are considered. The historical sea level data at the Golden Gate clearly shows an upward trend over the past 100 years (Figure 14). Model predictions groups indicate that sea level rise over the 21st century could accelerate (Hayhoe et al. 2004). For example, the relative sea level rise at the Golden Gate during the 20th century was approximately 13 cm. Towards the end of the 21st century, the sea level could increase another 19 to 41 cm (Hayhoe et al. 2004). The work of Knowles and Cayan (2002), which applies the UP model to San Francisco Bay to evaluate the effects of global warming on the Bay, indicates that higher salinity levels will exist in the Bay. It is suggested that the UP Model be tested over different periods within the forecast period to examine the effect of increasing sea level.

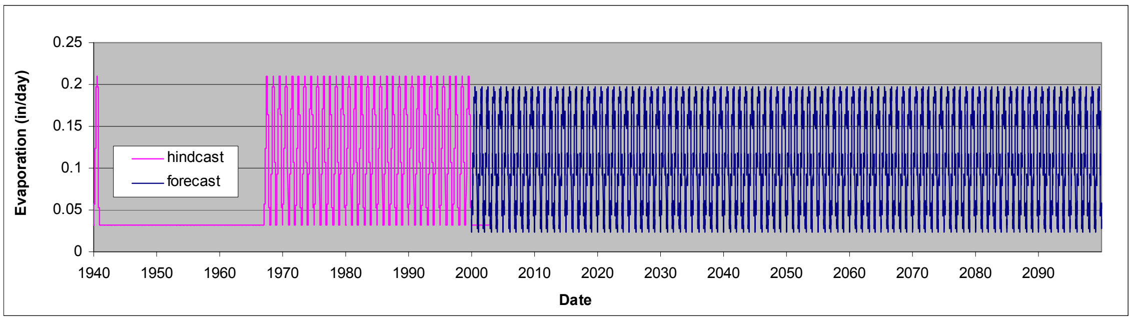


Figure 11. Time series of hindcast and forecast evaporation rates used by MBM.

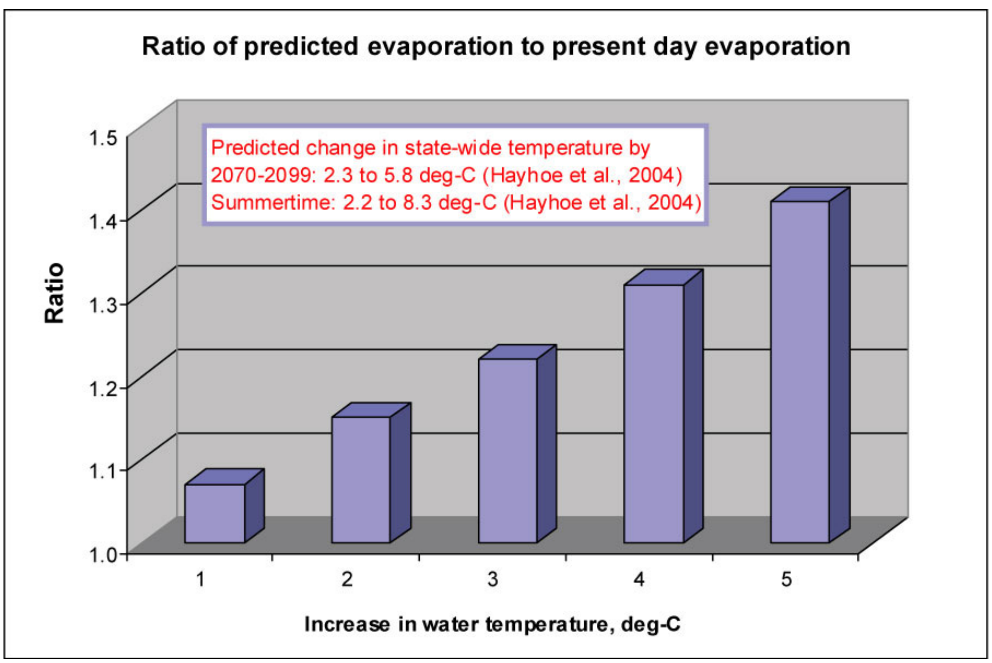


Figure 12. Dependence of evaporation on increased water temperature.

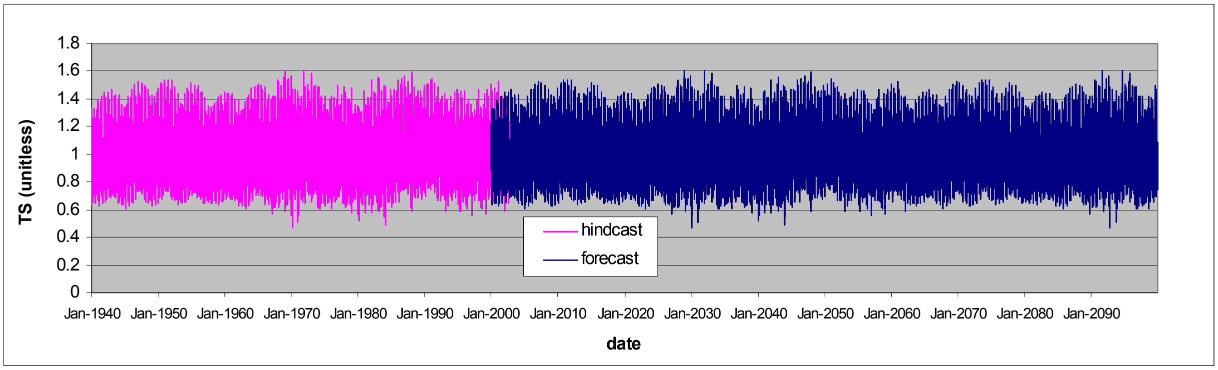


Figure 13. Time series of hindcast and forecast tidal states used in MBM.

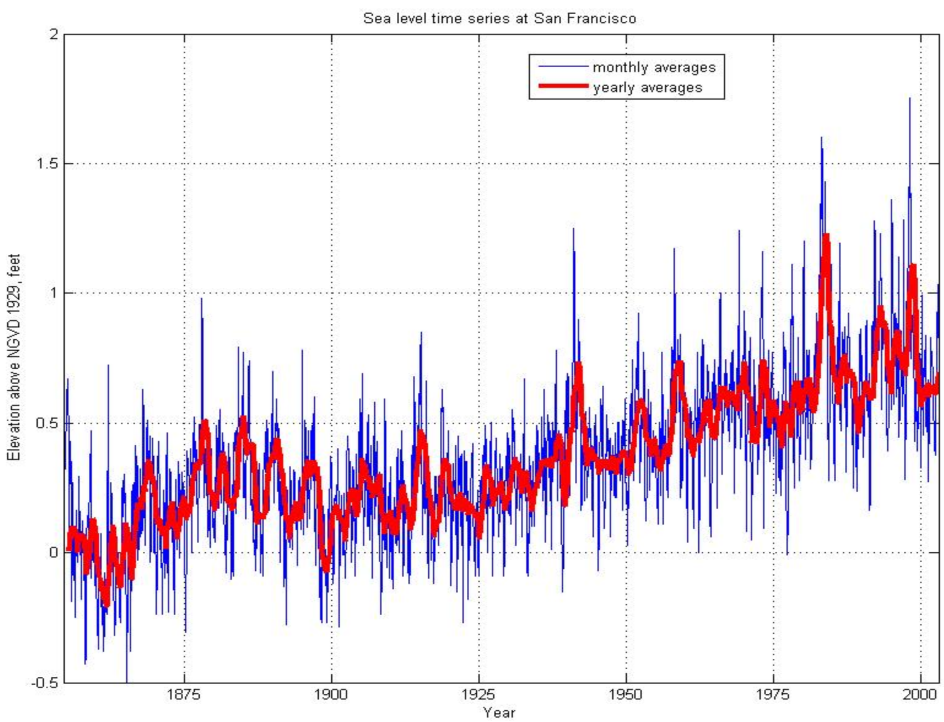


Figure 14. Relative sea level at Golden Gate, 1850 - present.

The last two input data sets examined consist of wind speed at San Francisco Airport (Figure 15) and salinity used for the ocean boundary condition (Figure 16). No specific suggestions are provided herein for changing wind speed. The boundary salinity data could be modified to add variability to the constant portions of the time series.

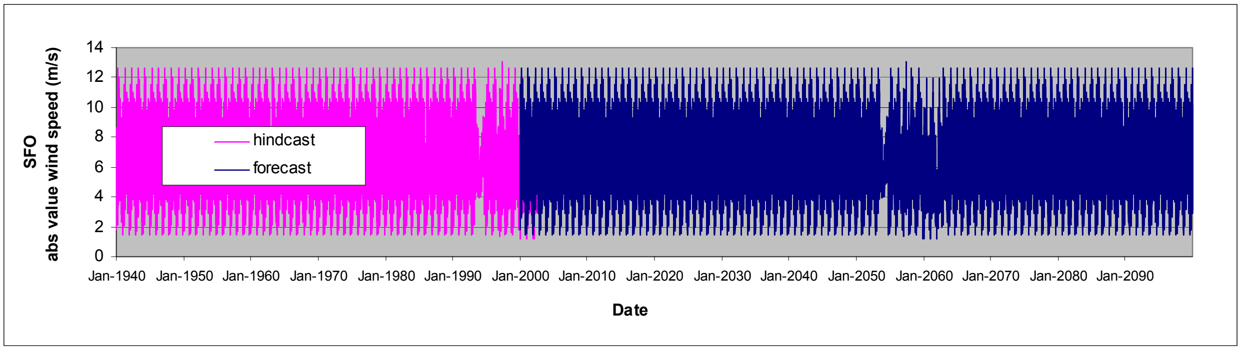


Figure 15. Time series of hindcast and forecast wind speed at SFO used in MBM.

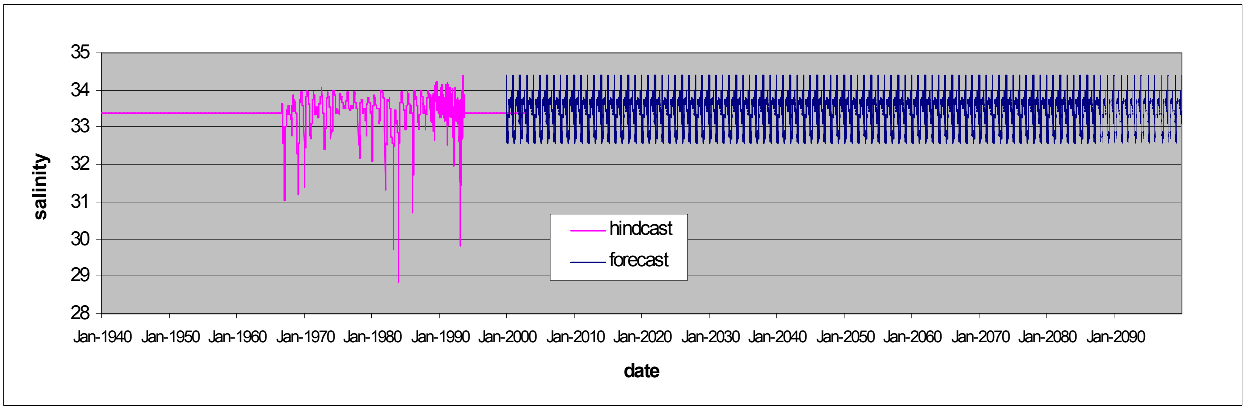


Figure 16. Time series of hindcast and forecast ocean boundary salinity concentrations (Farallon Islands) for used by MBM.

Model Initialization

The hindcast period began in 1940, for which model initial conditions were developed. The initial conditions include PCBs in bedded sediments, which were set to zero. As the model simulations proceed onward from 1940, it appears that the Bay's suspended solids undergo an adjustment period of a decade or so, as shown, for example in Figure 17. This is typically called a spin-up period, and is often unavoidable because actual initial conditions are not known. It is possible to remove the influence of the spin up period by either initializing the model earlier in time and ignoring the spin-up period in terms of reporting results, or delaying PCB loads into the Bay until after the spin-up period. For this modeling application, PCB loads were added during the spin-up period and could result in unrealistic PCB transport during that time period.

Also, in 1940 PCBs had already been discharged to the Bay (from as early as 1927) according to the Breivik curve analysis reported in the draft report. By about 1940, the loading of PCBs exceeded today's loading rates by about 20 times (as shown later in Figure 30), so the assumption that the sediments were free of PCBs in 1940 is not consistent with the Breivik curve approach.

Alternative choices exist for how the model is initialized. One choice, for example, would be to initialize the model to the year PCB discharges to the Bay were thought to have begun (1927). For that starting time it would be appropriate to initialize the sediments as

PCB-free. However, a drawback to this approach is that since the historical PCB loadings are so uncertain, those uncertainties continue to propagate over decades. On the other hand, if the model were initialized based on current PCB data, the Breivik curve analysis would not be needed. However, since only a limited number of cores of data will be available, this approach also introduces uncertainties. It is suggested that the model developers evaluate and compare alternative approaches to initializing the model.

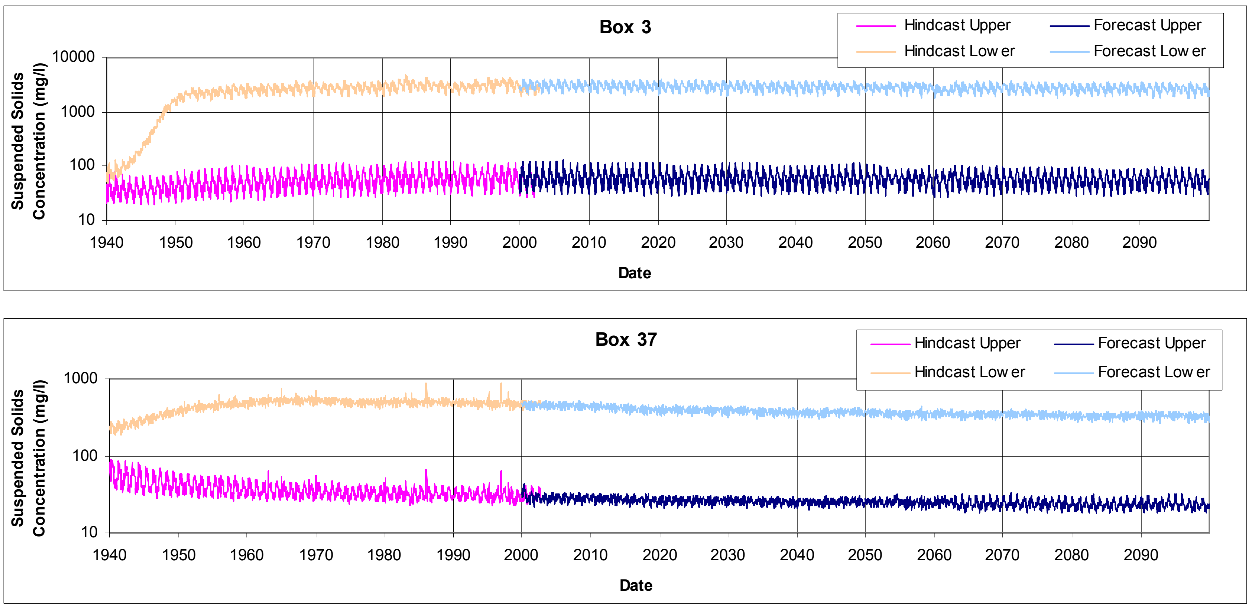


Figure 17. Time series of predicted suspended solids concentrations in boxes 3 and 37 illustrating the "Spin-up" Period.

Examination of UPS Model

The review of the UPS model consists of two parts:

- Model comparisons of predicted and observed suspended solids concentrations at locations throughout the Bay. It should be noted that the predicted concentrations are reported as one-day or 14-day averages over the volume of each box, while the observed values are near-instantaneous and at a particular depth, so the two sets of values are not expected to exactly match. More information on how the suspended solids data were collected can be found in the Attachments, provided by Dave Schoellhamer of the USGS. Where MBM V.1 results were available from the draft report, they are provided for comparison.
- Comparison of predicted and measured estimates of volumetric quantities of scour and deposition at several locations in the Bay.

A comparison of predicted and observed suspended solids concentrations at locations around the Bay for a 12-month period beginning in October 1998 is shown in Figures 18 through 22. The predicted concentrations are either 14-day averages (averaged over a spring-neap cycle) for each of the two layers within each box, or daily model output. As expected, the 14-day averages show less variability. At locations in the South Bay (Figures 18, 19, 20) the most noticeable features of the plots are the consistently higher model-predicted concentrations compared with USGS data. While some differences are expected, since the model predictions are volume averages, this behavior of higher predicted concentrations is consistent. This behavior is not observed, however, at Pier 24 (Figure 21) and Point San Pablo (Figure 22).

UPS V.1 (Figure 14 of draft report) UPS V.2b

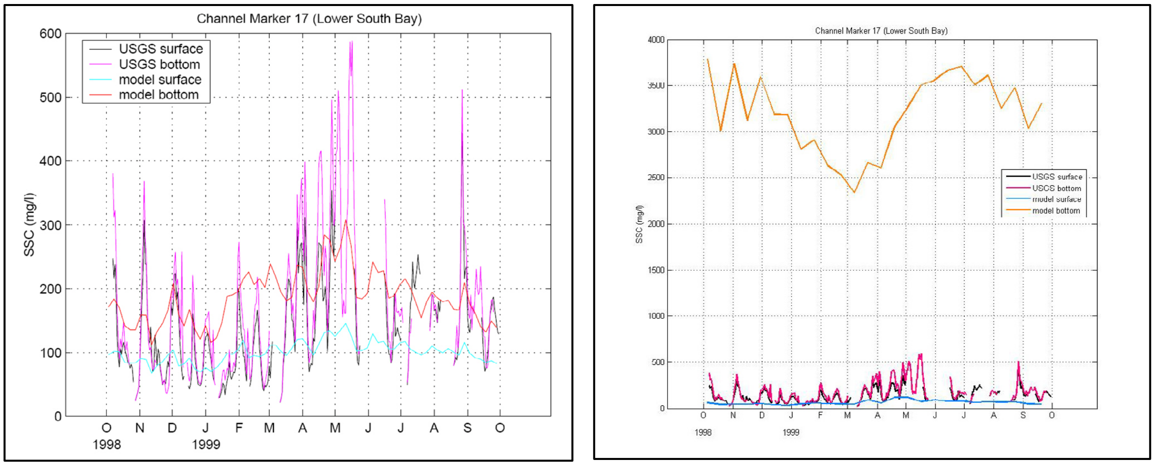


Figure 18. Comparison of predicted and observed suspended solids concentrations in box 3 (model predictions are 14-day averages). UPS V.1 results are shown for reference (from Leatherbarrow et al, 2005).

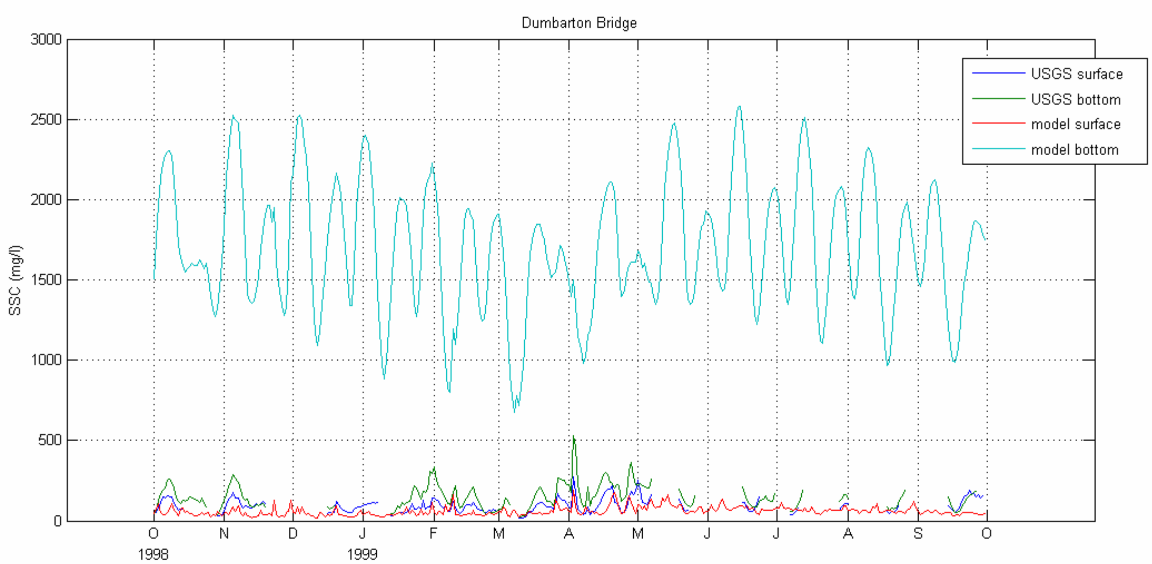


Figure 19. Comparison of predicted and observed suspended solids concentrations in box 4 (model predictions are daily output).

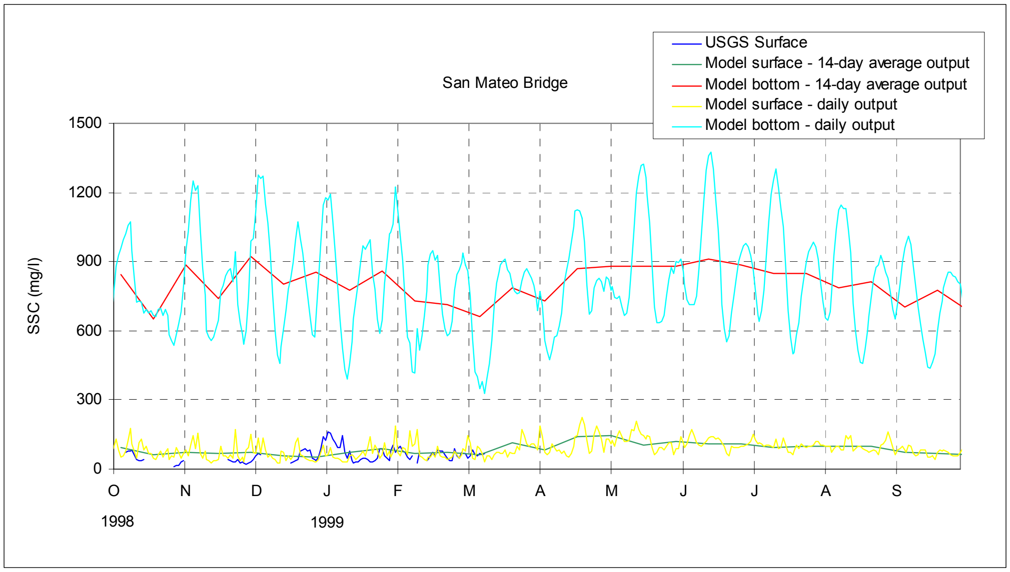
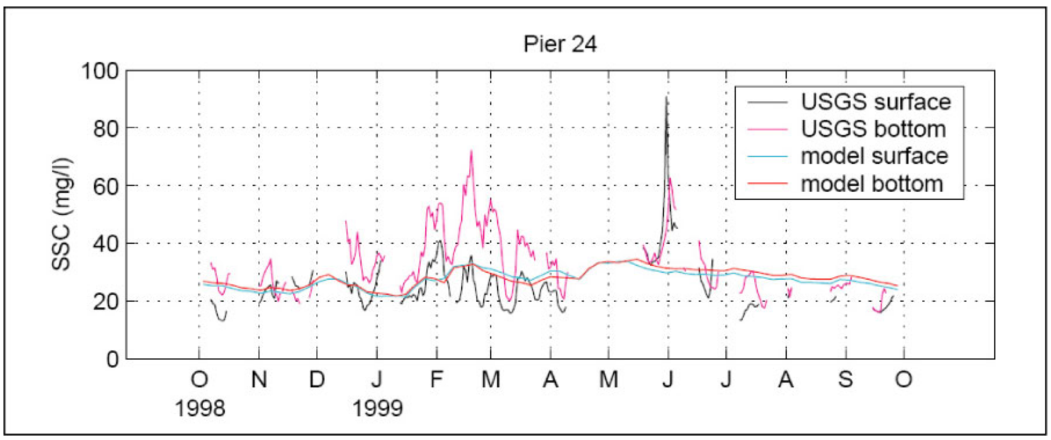


Figure 20. Comparison of predicted and observed suspended solids concentrations in box 8 (model predictions are daily output and 14-day averages).

UPS V.1 (Figure 13 of draft report)



UPS V.2b

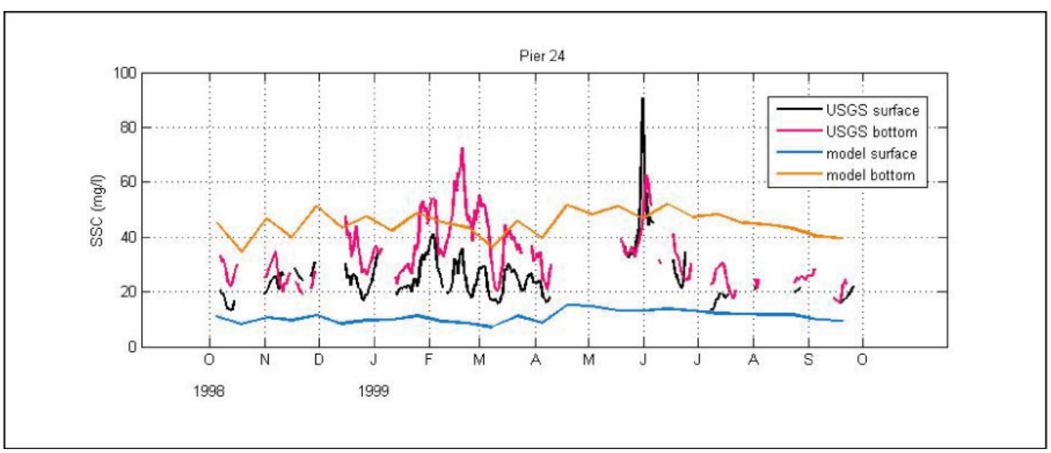


Figure 21. Comparison of predicted and observed suspended solids concentrations in box 18 (model predictions are 14-day averages). UPS V.1 results are shown for reference (from Leatherbarrow et al, 2005).

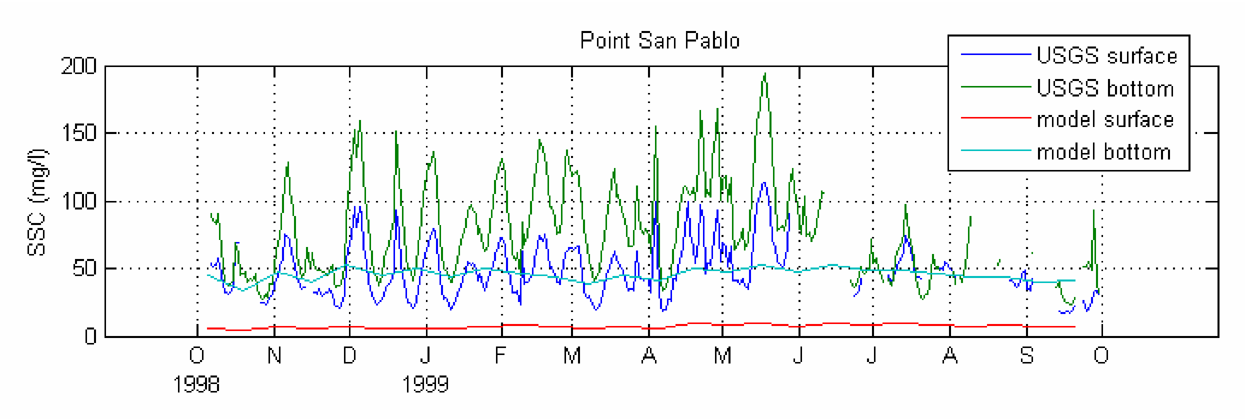


Figure 22. Comparison of predicted and observed suspended solids concentrations in box 22 (model predictions are 14-day averages).

Figure 23 shows representative results for 10 boxes throughout the Bay, from Lower South Bay to Suisun Bay for the year 1999. These results again show high suspended solids concentrations in the South Bay, which dramatically decrease by box 15 in the Central Bay. It is suggested that implications of the high concentrations of suspended solids in the lower layer in the South Bay on PCB fate and transport be examined.

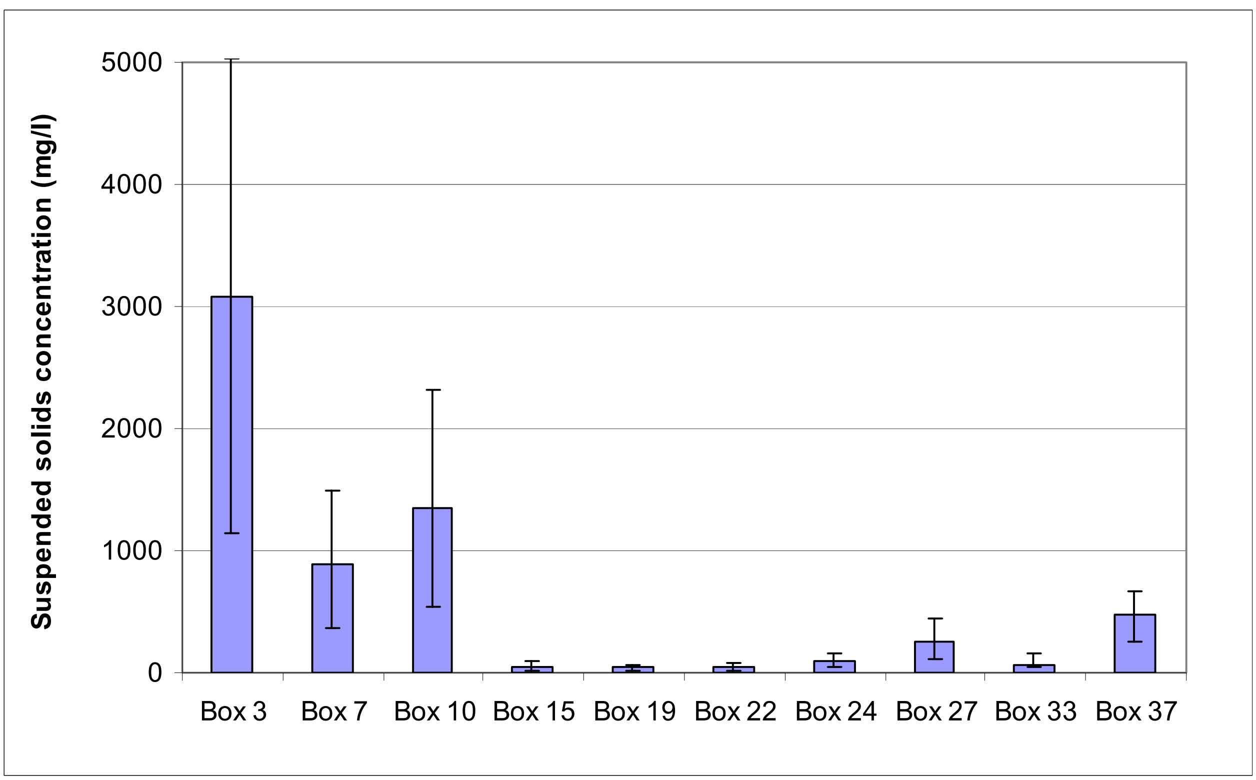


Figure 23. Year 1999 average and range of layer 2 daily predicted suspended solids concentrations at locations around the Bay.

The second part of the UPS review focuses on predicted changes in bed elevations, and predicted cumulative amounts of erosion and deposition at locations where estimates have been made of sediment deposition and erosion. Figure 24 shows cumulative predicted bed elevation changes at six locations around the Bay, from Lower South Bay to Suisun Bay. The feature that is of most interest here is the rapid changes that occur during the first ten years or so following the beginning of model simulations. These rapid changes appear to be a manifestation of model adjustments to the initial conditions, as it appears that the model predicted bed elevation changes are much more gradual later in the simulations. This suggests, as discussed earlier, that if this phenomena is model-generated and not a feature of the Bay, that an adjustment in the spin-up period should be made to prevent this from impacting model predictions.

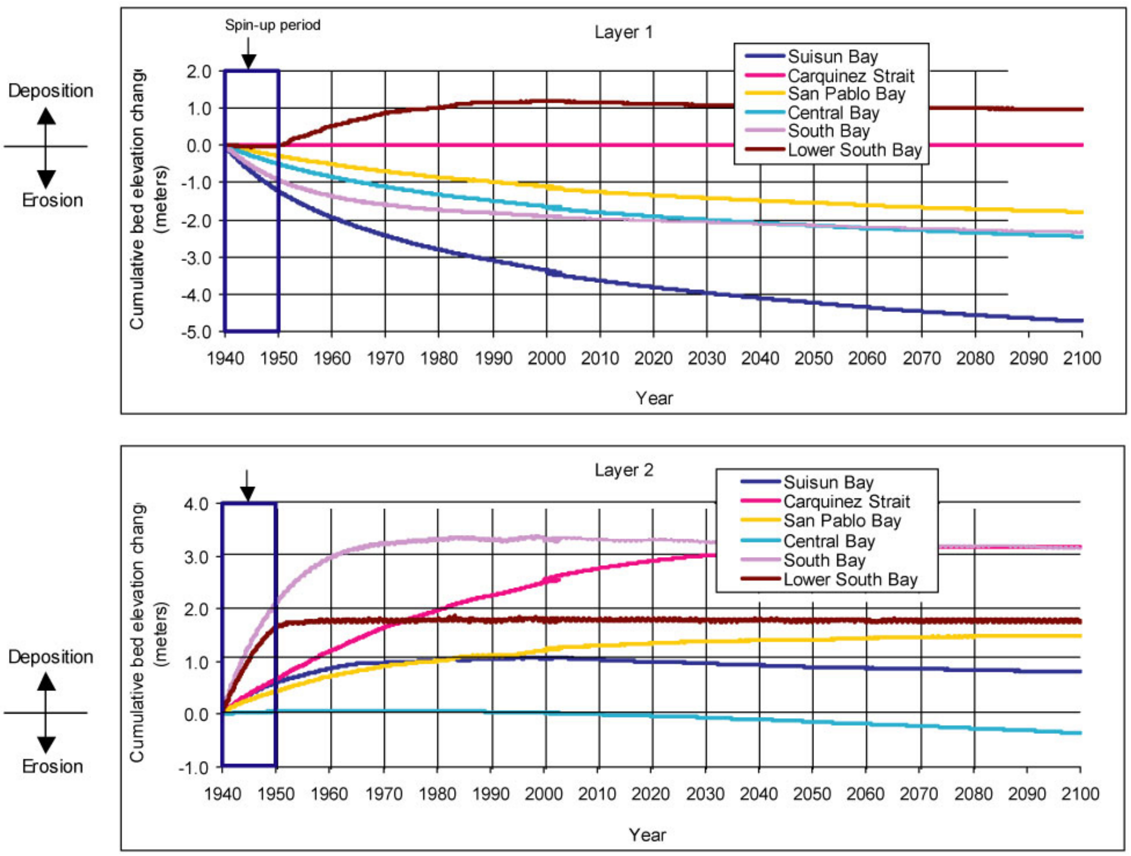


Figure 24. Bed elevation changes at selected locations in the Bay.

The cumulative predicted bed elevation changes are summarized in Table 4 for the six locations. The simulation time interval is subdivided into time intervals of 1940-1950, 1950-2000, and 2000-2100. Changes in bed elevations during the first ten years at locations such as Suisun Bay, Lower South Bay, and South Bay are comparable to or higher than during the combined remaining time periods. Should bed elevation data exist at these various locations, such data can be compared against these predictions.

A potential issue that may arise in prediction of PCB transport is whether predicted burial of PCBs (defined as PCBs buried more than a meter into the sediments) is affected by the spin-up period. Figure 25 shows the mass of PCB deposition by pathway from 1940-2000. Note that within the first 10 to 15 years the mass of PCBs buried is about 10 percent, and stays there for the remainder of the simulation. It is suggested that the impacts of the spin-up period on PCB burial be investigated.

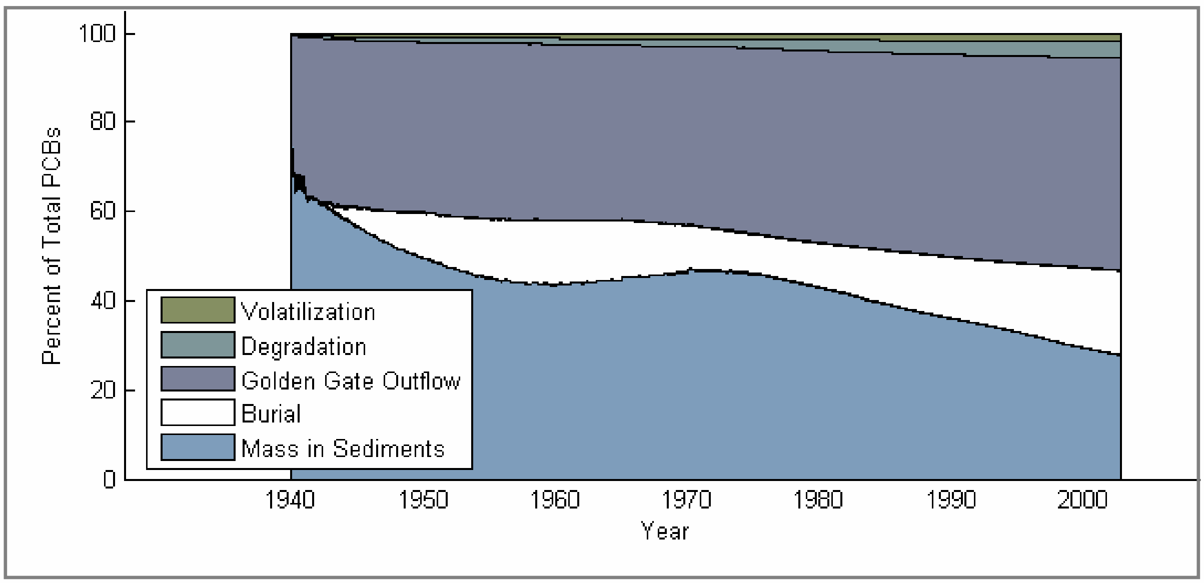


Figure 25. Predicted percentage of PCB mass by pathways with San Francisco Bay.

Table 4 shows the predicted cumulative bed elevation changes throughout the Bay. Note that during the spin-up period from 1940-1950, bed elevation changes can be quite significant for such a short period of time. For example, for the lower level in Suisun Bay, 0.6 meter is predicted to erode from 1940 to 1950, while over the next 50 years, only 0.5 meter is predicted to erode. It is suggested that the model developers review whether the spin-up period has an artificial effect on the eroded depths.

By examining the cumulative changes of the box volumes and sediment accumulation depths, it is possible to estimate the change of water volume and sediment volume within the Bay. Model predictions are shown in Table 5, compiled with several other estimates. The volume predicted by MBM is between the two estimates.

Table 4
Predicted Cumulative Bed Elevation Changes Throughout the Bay

Change in Layer 1 Bed Elevation (meters)

	Suisin Bay	Carquinez Strait	San Pablo Bay	Central Bay	South Bay	Lower South Bay
1940-1950	-1.2	0	-0.28	-0.50	-0.92	-0.0020
1950-2000	-2.1	0	-0.82	-1.1	-0.97	1.2
2000-2100	-1.4	0	-0.69	-0.81	-0.44	-0.22

Change in Layer 2 Bed Elevation (meters)

	Suisin Bay	Carquinez Strait	San Pablo Bay	Central Bay	South Bay	Lower South Bay
1940-1950	0.60	0.66	0.43	0.050	2.1	1.6
1950-2000	0.46	1.8	0.78	-0.017	1.2	0.13
2000-2100	-0.26	0.67	0.27	-0.39	-0.19	0.0069

Table 5
Predicted Volume of Water in Bay Compared With Other Estimates

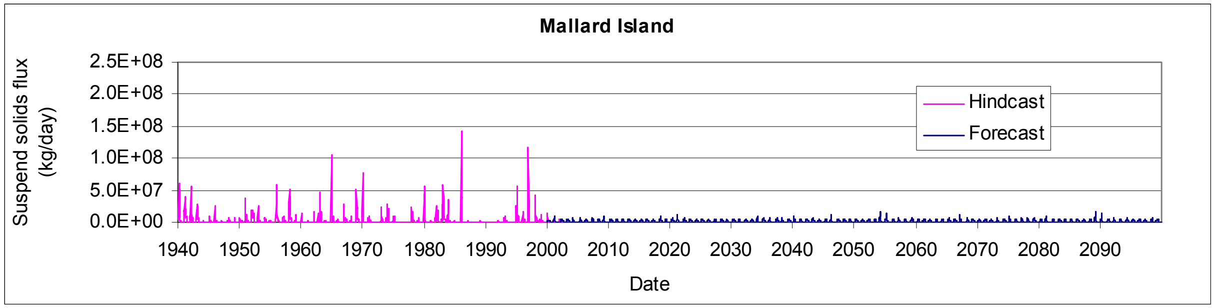
Estimate	Volume (Mm3)	Year	Source
Multibox Model	6101 - 6773	Hindcast (1940-2002)	Model Simulation results
USGS Estimate	8446	2002	http://sfbay.wr.usgs.gov/access/Bathy/geostats.html
Jassby	5500	1992	J. Davis single box model report

Table 6 summarizes estimates of sediment volume changes within the Bay. Where data are available, these estimates are generally consistent with published estimates.

Figure 26 provides support for the Bay-wide model prediction that shows the Bay is erosional. The average hindcast sediment flux out of the Golden Gate ($1.2x10^7$ kg/day) exceeds the average influxes from Mallard Island ($2.72x10^6$ kg/day) and from tributaries ($2.6x10^6$ kg/day) combined. These results are in general agreement with those in McKee et al. (2002) at: http://www.sfei.org/rmp/reports/Sediment_loads_report.pdf.

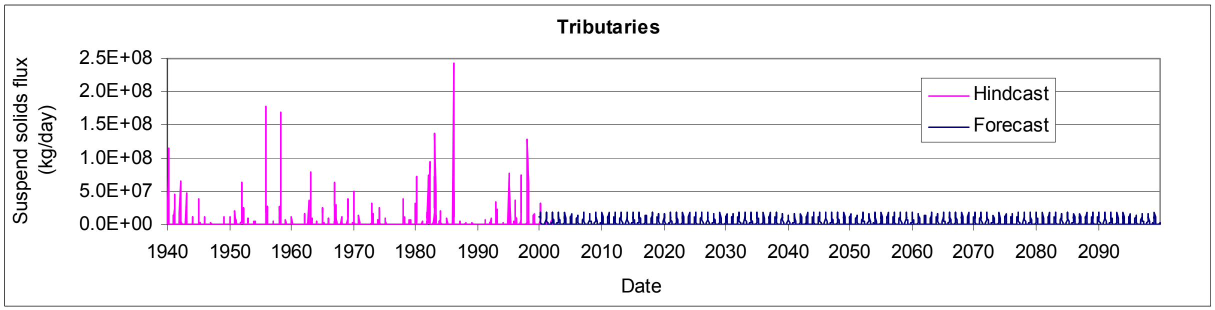
Table 6
Comparisons of Model Predicted Volume Changes with Volumes of Scour and Deposition

Location	Boxes	Time Period	Model Predicted Volume Change (Mm3)	Published Estimate (Mm3)	Regime Type
Suisin Bay	29-41 (USGS)	1942-1990	24.0	61	erosional
San Pablo Bay	23-28 (USGS)	1951-1983	24.9	7	erosional
South Bay	1-14 (USGS)	1956-1983	46.6	45	erosional
Lower South Bay	1-4 (SFEI)	1942-1990	-30.1	NA	depositional



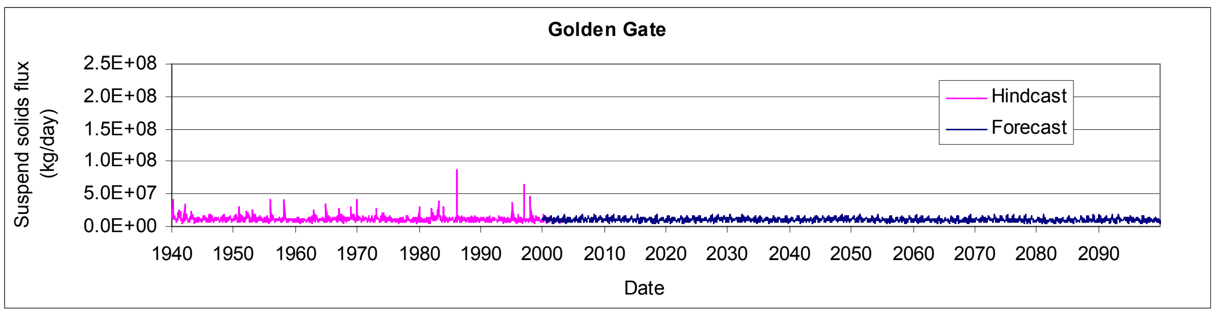
Mallard Island Flux (kg/day)

	Hindcast	Forecast
Min	3.08E+02	-1.35E-10
Max	1.42E+08	1.61E+07
Avg	2.72E+06	1.42E+06
Std	8.76E+06	1.81E+06



Tributaries Flux (kg/day)

	Hindcast	Forecast
Min	1.00E+01	3.65E+04
Max	2.43E+08	1.88E+07
Avg	2.70E+06	3.07E+06
Std	1.31E+07	4.75E+06



Golden Gate Flux (kg/day)

	Hindcast	Forecast
Min	5.02E+06	4.59E+06
Max	8.60E+07	1.93E+07
Avg	1.15E+07	1.04E+07
Std	4.80E+06	2.77E+06

Figure 26. MBM-predicted net loading and loss of suspended solids flux in San Francisco Bay.

Comparison of Predicted and Observed PCB Concentrations

In this section, comparisons are made between observed and predicted PCB concentrations in the water column (both total and dissolved) and in the sediments. The results appear to show that the predicted concentrations in both water and sediments generally exceed observations. To illustrate this, Figure 27 shows the predicted one-day average total PCB concentrations during the hindcast and forecast periods, along with the mean of observed data. Locations shown are for Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Lower South Bay. In all cases, the hindcast predictions exceed the observations, typically by a factor of 5 to 10 times. The figures also illustrate the scaling that was performed in the surface sediment for the forecast to bring the predictions into agreement with observed data.

Figure 28 shows predicted dissolved water column PCB concentrations for year 2000 at three locations (Lower South Bay, Central Bay, and San Pablo Bay) for both upper and lower layers, and RMP data for comparison. The predicted values exceed observations by about 3 to 10 times. In the surface sediments, the same results apply, where higher than observed surface PCB concentrations are predicted. A depth profile of sampled PCBs in 1990 (from Venkatesan et al, 1999) was plotted against predicted profiles for 1970 and 1990 (see Figure 29). Based on the bathymetry of San Pablo Bay, the 1990 profile is located in the channel; it exceeds the observed profile data by 5 to 10 times. It is noted that the predictions for 2010 in the channel match the data for Venkatesan et al. (1999); because of the scaling, these data more closely match observed data. It is suggested that the need for this scaling be eliminated by determining the cause of the generally elevated predictions for PCBs. One cause could be that in the model, larger historical PCB loadings are input to the Bay than actually occurred (see the following section).

A second figure for predicted sediment PCBs over depth is shown in Figure 30. Predicted results during the hindcast period range from 200 ng/g to 600 ng/g near the surface to less than 200 ng/g near the 100 cm depth. Based on near-surface PCB measurements in the Lower South Bay (10 ng/g to 25 ng/g) the predictions over-estimate observations by a factor of 10 or more. Again, the data shown for 2010 are subsequent to the forecast scaling.

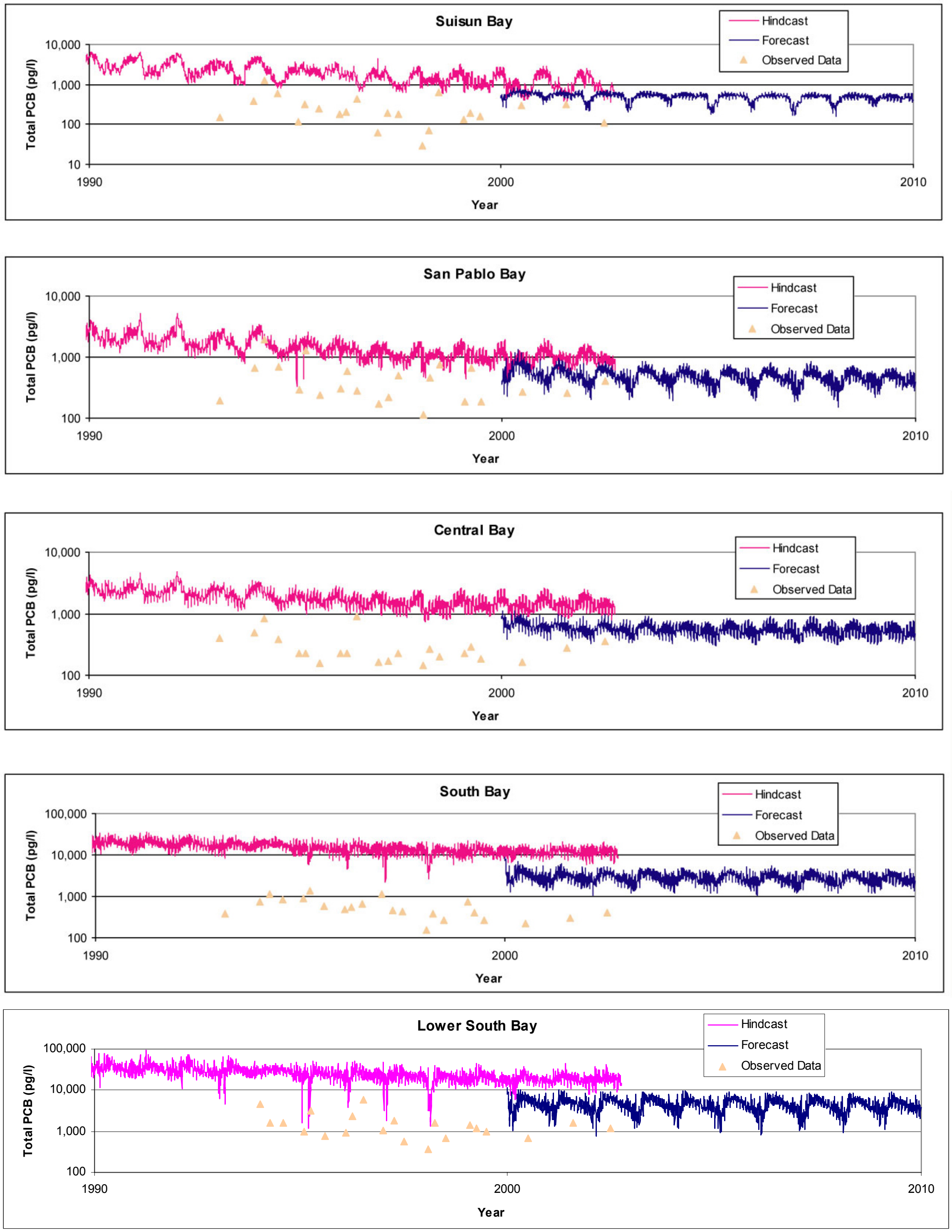


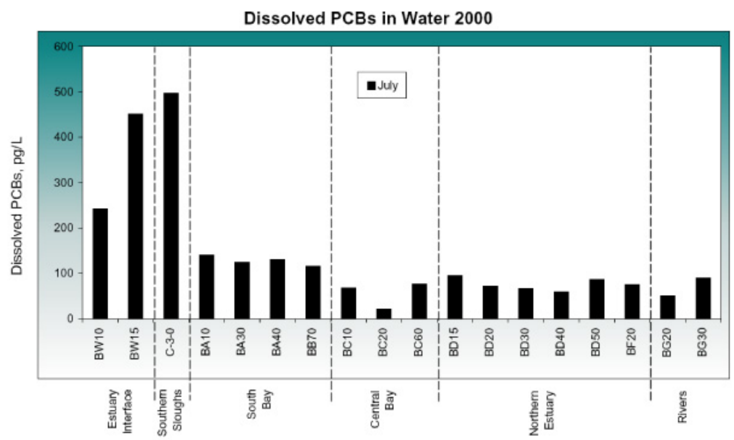
Figure 27. Comparison of observed data to MBM-predicted total water column PCB concentrations over hindcast and forecast periods.

Range of Model Predicted Dissolved (pg/l)- Year 2000

Location	Box	Upper Layer	Lower Layer	RMP Data	RMP Data Location
Lower South Bay	3	1200-1800	1200-1800	124 - 141	BA10, BA30
Central Bay	19	280-460	260-450	22 - 116	BB70, BC10, BC20, BC60
San Pablo Bay	25	195-435	210-440	60 - 96	BD15, BD20, BD30, BD40, BD50

Range of Model Predicted PCBs in Surface Sediment (ng/g) - Year 2000

Location	Box	Upper Layer	Lower Layer	RMP Data	RMP Data Location
Lower South Bay	3	137-152	127-141	5.2 - 9.5	BA10, BA30
Central Bay	19	4.8-5.6	41-43	0.2 - 26.6	BB70, BC11, BC21, BC60
San Pablo Bay	25	7.3-8.1	23-27	0.2 - 9.9	BD15, BD22, BD31, BD41, BD50



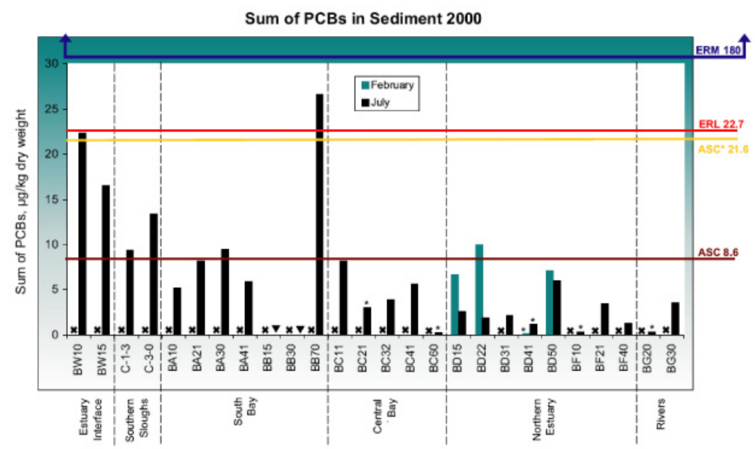


Figure 28. Comparison of Year 2000 measured and predicted PCB concentrations – dissolved and surface sediment.

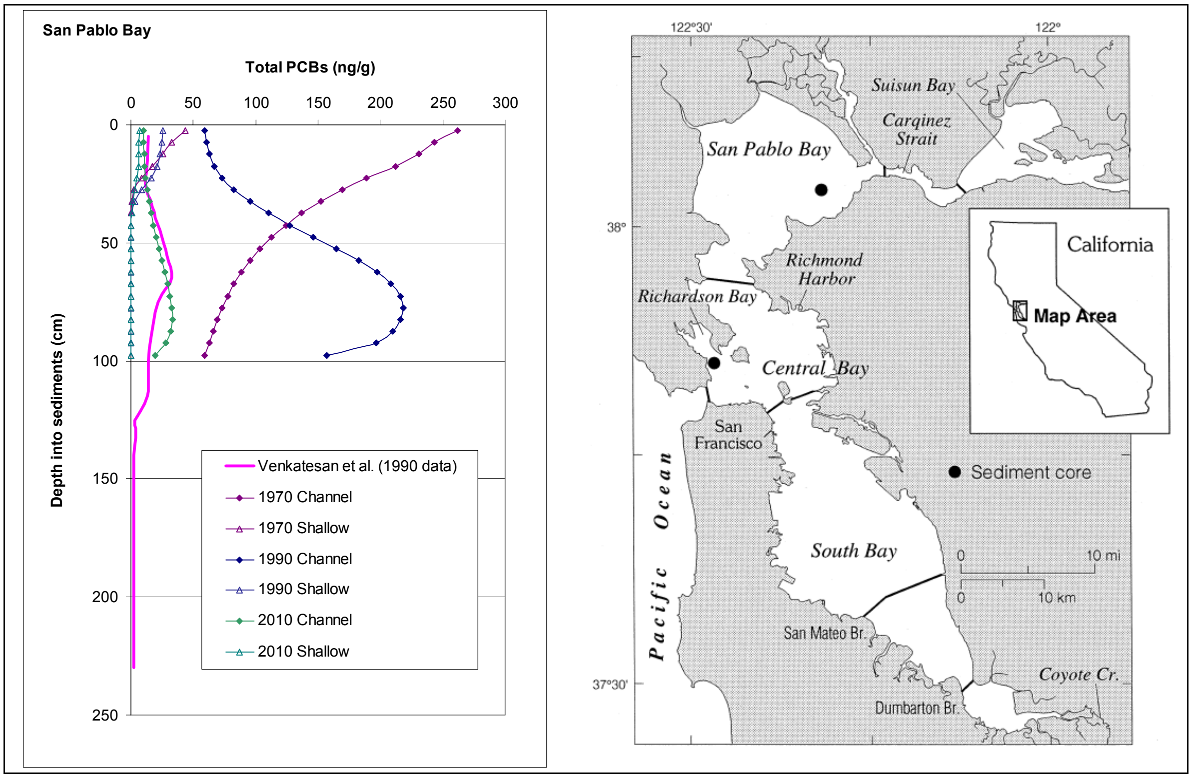


Figure 29. Depth profiles of PCBs in San Pablo Bay sediments.

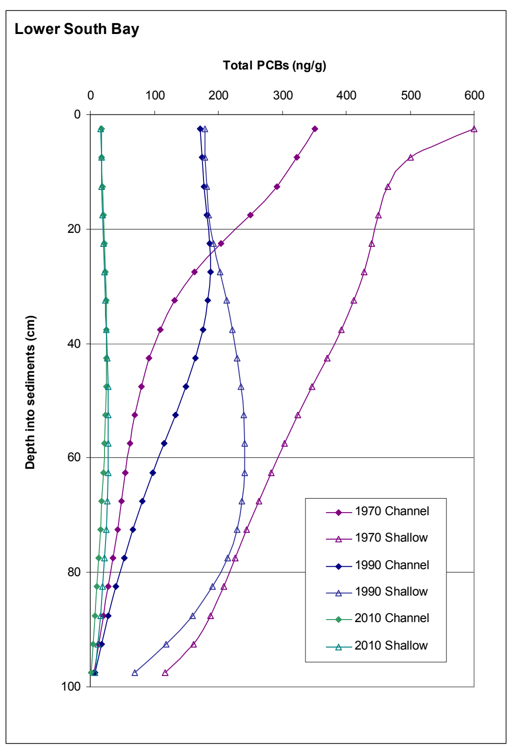


Figure 30. Depth profiles of PCBs in Lower South Bay sediments.

PCB Loading to the Bay

Figures 31, 32, and 33 were constructed to verify that the loading estimates to the Bay are consistent with the estimates in the draft report, and that the PCB mass within the Bay is declining over time. Based on calculations performed during this review, these observations are true. Several issues are apparent from these figures:

- PCB loading to the Bay by 1940, according to Figure 31 was quite large, perhaps an order of magnitude greater than today. Thus, it is likely that there would have been significant quantities of PCBs in the Bay by then. Thus, setting sediment PCB levels to zero in 1940 is probably not realistic.
- Since about 1990, according to the model, the total amount of PCBs remaining in the Bay is decreasing. To reduce (or remove) the dependence of model predictions on the highly uncertain loading reconstruction, an alternative approach to initializing the model could be to use the coring data to be collected in 2005 and estimates of present and future of PCB loads, rather than trying to recreate such a long hindcast period. Figure 34a illustrates a factor of 10 load change for PCBs to the Bay over the hindcast and forecast periods. This range is the same chosen by Breivik in Figure 8 of the draft report. The hindcast and forecast total PCB concentrations in the water column for the Lower South Bay and Suisun Bay are superimposed on the PCB load in Figure 34b. It is clear from this figure that the predicted concentrations respond very strongly to loading changes. This indicates that, should evidence support significant decreases in loading, predicted concentrations could be much more in-line with observations.

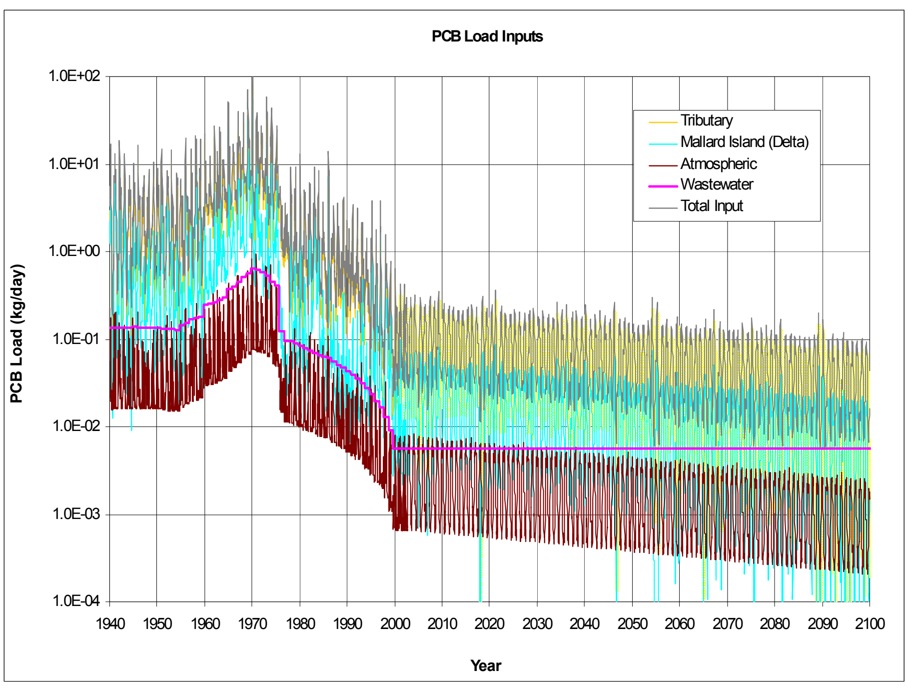


Figure 31. Total PCB loads to Bay based on approach from V.1 draft report.

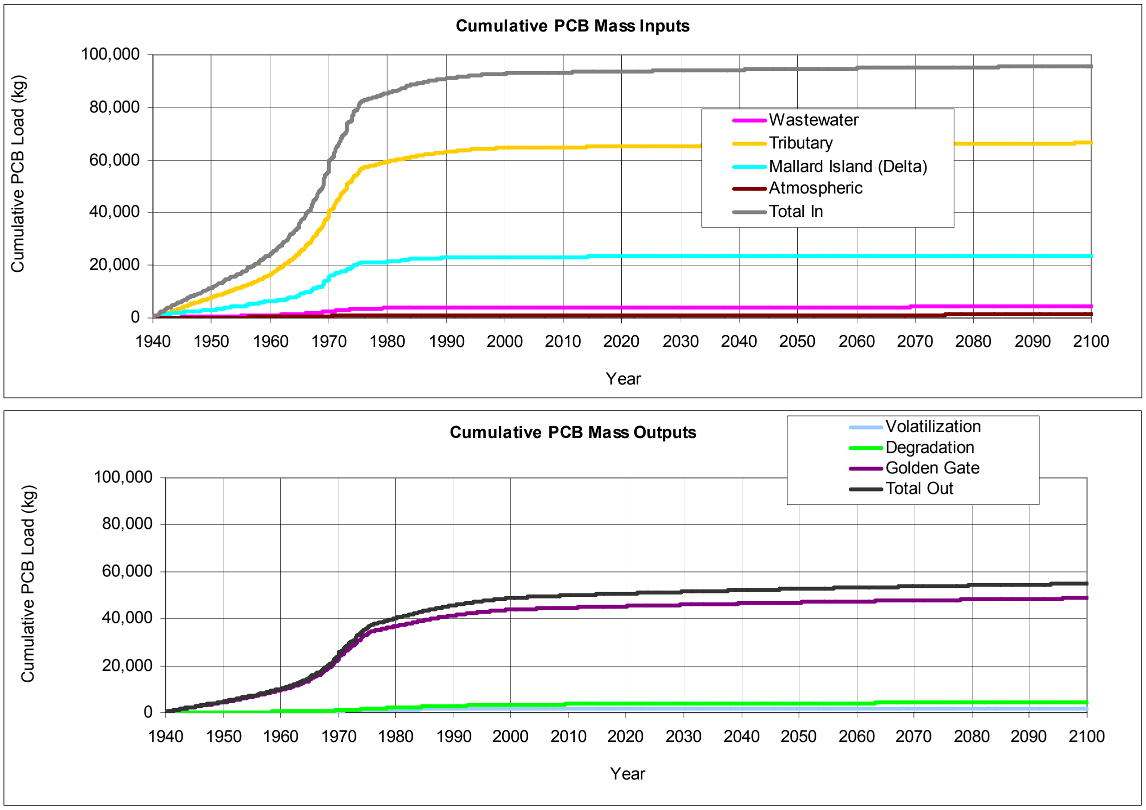


Figure 32. Cumulative PCB inputs and losses based on model V.2b predictions.

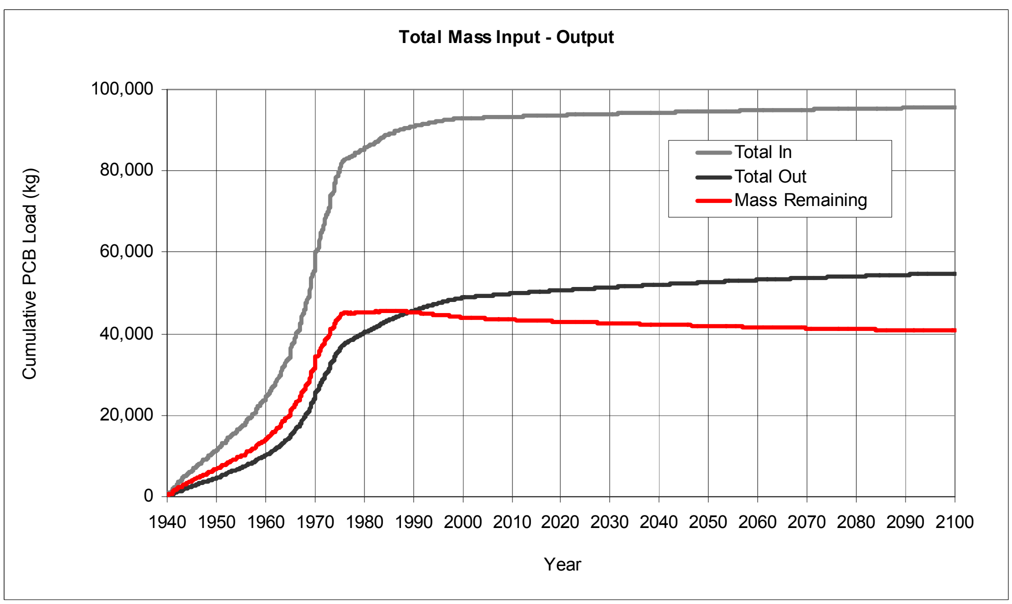


Figure 33. Cumulative PCB mass in and out of Bay based on model V.2b predictions.

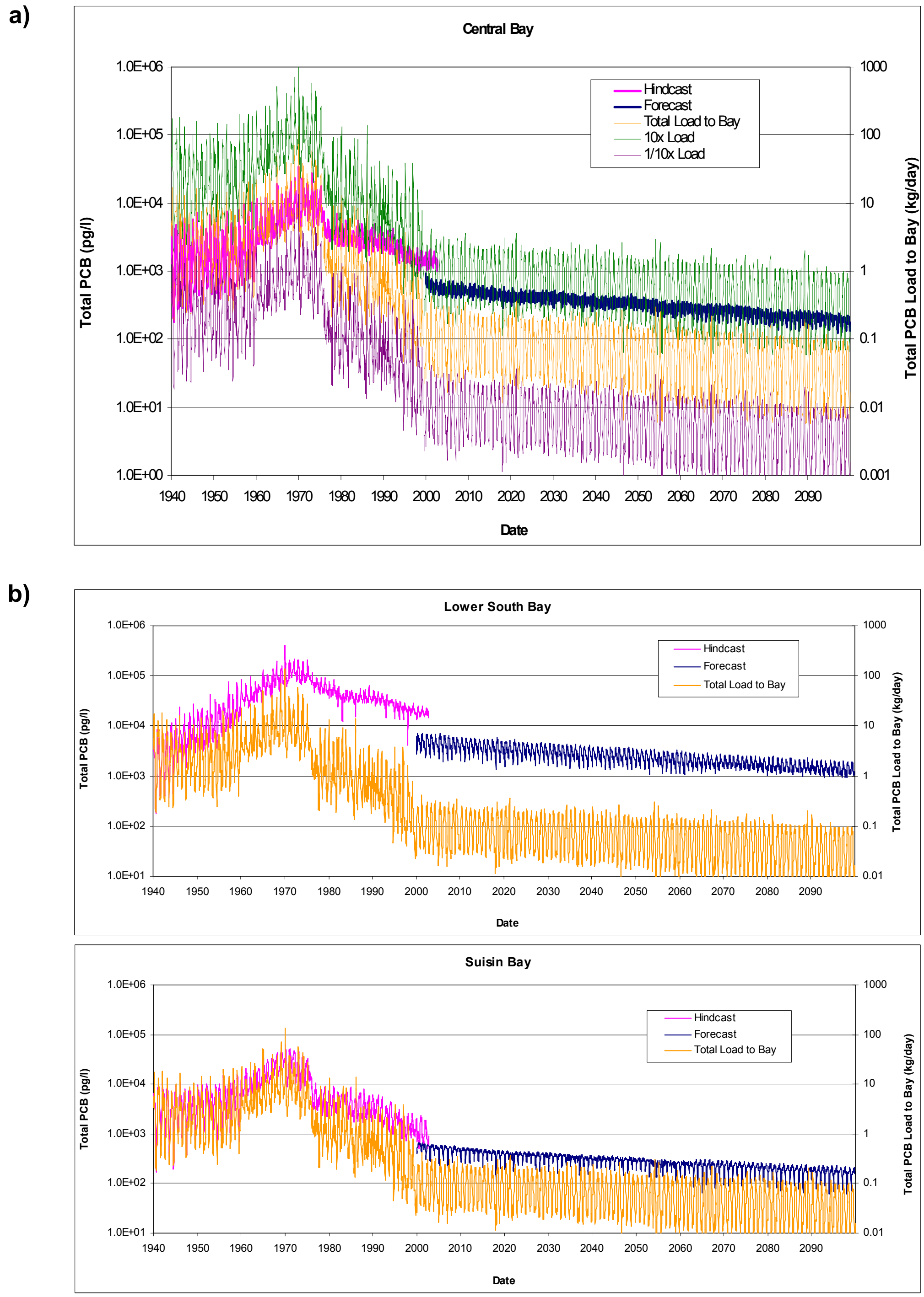


Figure 34. a) Possible range in PCB loading to the Bay. b) PCB total concentrations in Lower South Bay and Suisun Bay and total PCB load to the Bay.

PCB Modeling

The present version of MBM simulates the fate of a single congener (PCB-118) as representative of PCB in the Bay. Table 7 shows properties of five PCB congeners, including PCB-118, in order to illustrate the variability of selected properties of the congeners. PCB-118 has properties that are intermediate with respect to the others shown. The two less chlorinated PCBs are expected to be present in the water column with a higher dissolved fraction, and thus to volatilize more quickly than PCB-118. Thus, supposing that lighter PCBs were discharged to the Bay decades ago, it is plausible that only a small fraction would remain today**.** Venkatesan et al. (1999) states that the PCB congeners 77, 105, and 118 constituted 0 % to 22 % of the total PCB measured at the core sample in San Pablo Bay. This information suggests that modeling only PCB-118 should perhaps be re-evaluated.

In contrast, according to the MBM over 40 percent of the PCB-118 discharged is predicted to remain in the Bay today (see Figure 33). The more heavily chlorinated PCBs would likely be present at even higher percentages than PCB-118. Suggestions to address these issues are:

- Other PCB modeling studies could be reviewed to see how PCBs were modeled and the reasons for the choices. Alternatives, in addition to total PCBs, would include multiple congeners or homologs.
- The conceptual model of PCBs, once completed, can be used to guide the modeling approach. One particular issue to address is whether the more heavily chlorinated PCBs completely, or only partially, dechlorinate. Not only would the decay rate be an issue, but degradation products could also be present. A possible alternative could be to model a single congener/homolog but to set the decay rate to zero. (The attenuation factor could still be nonzero).
- A sensitivity analysis could be conducted of the fate of different congeners in the Bay. It may be that the less chlorinated PCBs, even if they were discharged many years ago, may not exist today. If so, there would be no need to model such congeners, but instead reduce the mass loadings from those congeners that are still present.

Table 7

Properties of Selected PCB Congeners

PCB Congener	Log Kow	Log (foc*Koc)	K_H (Pa*m^3*mol^{-1})	Percent dissolved	Volatilization Half-life (days)
18	5.4	3.5	20-101	80	10
66	6.0	4.1	14-84	50	16
118	6.7	4.8	3.94	16	50
153	7.4	5.5	2-43	4	200
194	8.7	6.8	10-47	0.2	4000

REFERENCES

Hayhoe, K., Cayan, D., Field.C.B., Frumhoff, P.C., Maurer, E.P., Miller, N.L., Moser, S.C., Schneider, S.H., Cahill, K.N., Cleland, E.E., Dale, L., Drepek, R., Hanmann, R.M., Kalkstein, L.S., Lenihan, J., Lunch, C.K. , Neilson R.P., Sheridan, S.C., and Verville J.H. 2004. Emission Pathways Climate Change, and Impacts on California. Proceedings of National Academy of Sciences. Vol. 101, No. 34.

Hornbuckle, K.C., J.D. Jeremiason, C W Sweet, J.D.J., and Eisenreich, S.J. 1994. Seasonal Variations in Air-Water Exchange of Polychlorinated Biphenyls in Lake Superior. *Environmental Science and Technology*, **28**, 1491-1501.

Knowles,N. and D. R. Cayan. 2002. Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. Geophysical Research Letters, Vol. 29, No 18, 1891, pp38-1 to 38-4.

Leatherbarrow, J.E., J.J. Oram, and J.A. Davis. 2005. *A Model of Long-Term PCB Fate and Transport in San Francisco Bay, California.* SFEI Contribution 388. February.

Lionberger, M.A. 2003. *A tidally –averaged sediment transport model of San Fransicio Bay, California.* Masters thesis, University of California, Davis.

Uncles, R.J. and Peterson, D.H. 1995. A computer model of long-term salinity in San Francisco Bay: sensitivity to mixing and inflows. Environments International , **21**(5), 647-656.

Uncles, R.J. and Peterson, D.H. 1996. The long-term salinity field in San Francisco Bay: sensitivity to mixing and inflows. Continental Shelf Research, **15**(15), 2005-2039.

Venkatesan, M.I., de Leon, R.P., van Green, A., and Luoma, S.N. 1999. Chlorinated hydrocarbon pesticides and polychlorinated biphenyl in sediment cores from San Francisco Bay. Marine Chemistry, **64**, 85-97.

ATTACHMENTS

PowerPoint Presentation: USGS Component of the Multi-box model
By: David Schoellhamer

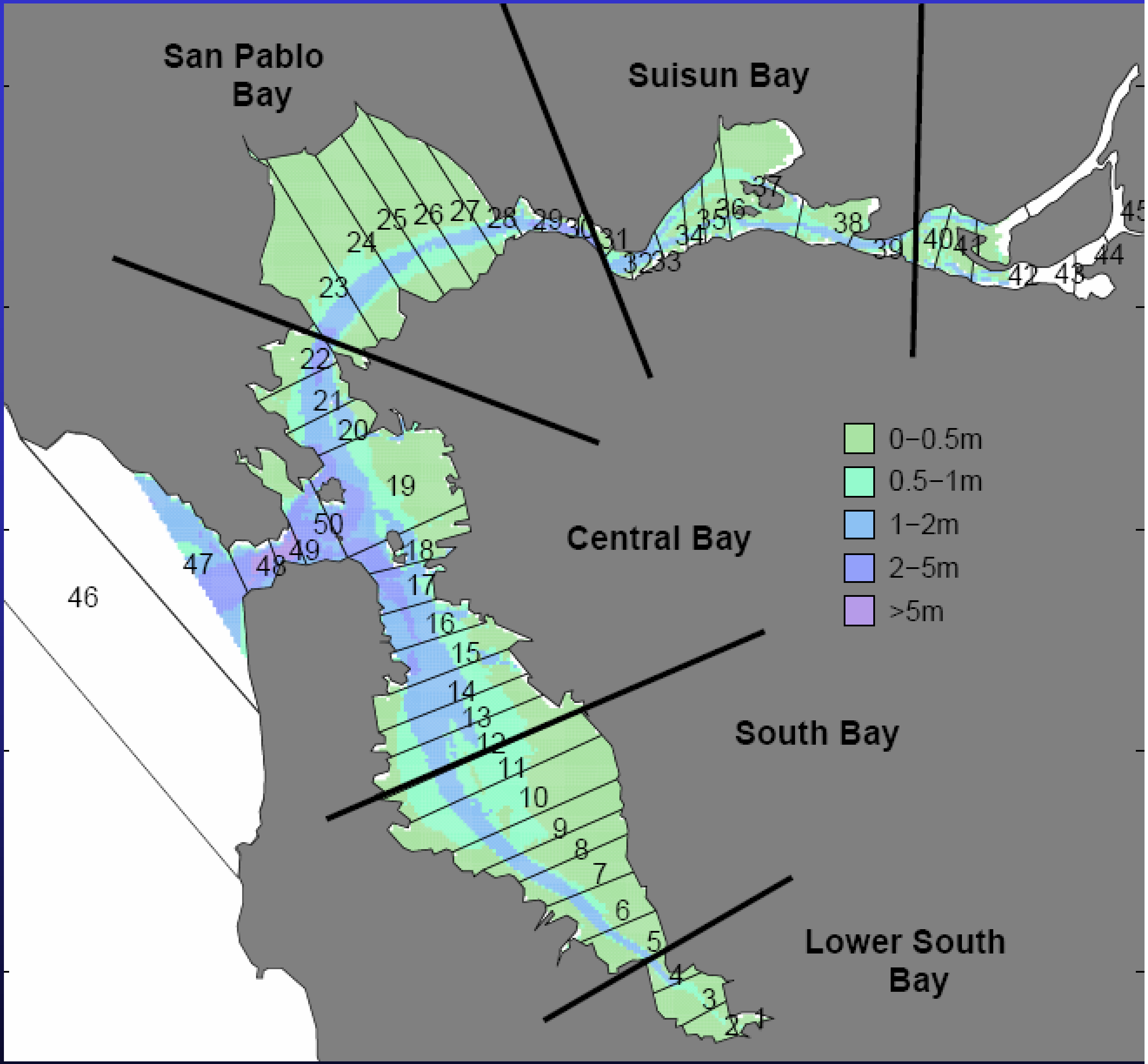
Email: *Re: Tetra Tech Review of Multibox Model*
By: John J. Oram and Andrew J. Gunther

Email: *Multibox Model*
By: John J. Oram, Katherine Heidel and Bill Mills

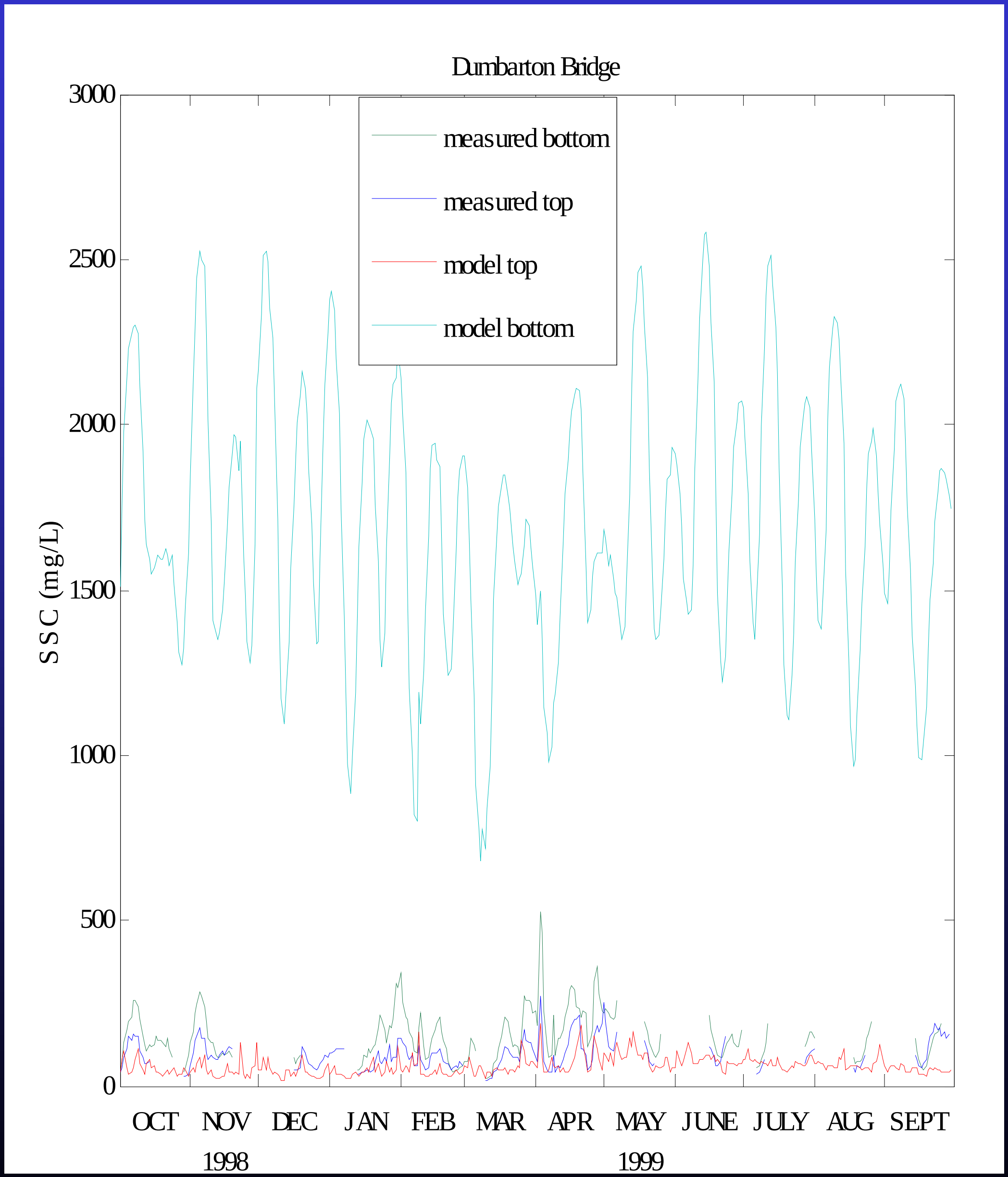
Email: *Draft PCB Model Review*
By: John J. Oram , Andrew J. Gunther , David Schoellhamer, and Bill Mills

USGS component of the Multi-box model

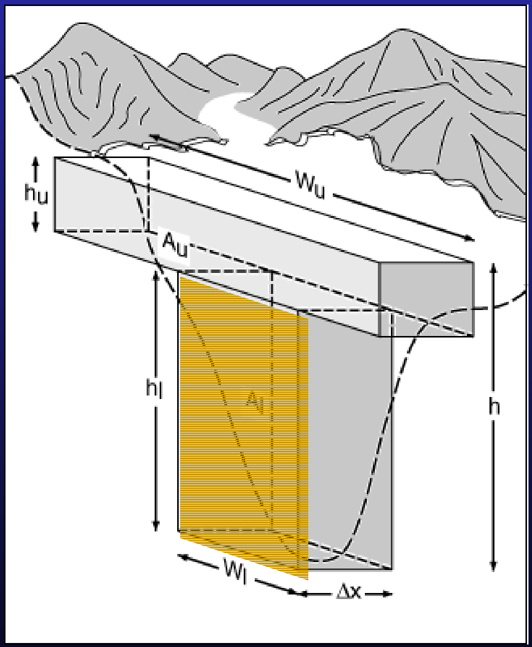
David Schoellhamer



Problem



Bad comparison of SSC in lower segment in South Bay



USGS

Reasons

- Calibration to bathymetric change
- Lower segment height
- Lower South Bay salt calibration
- Lateral averaging
- Lower South Bay tributary loads

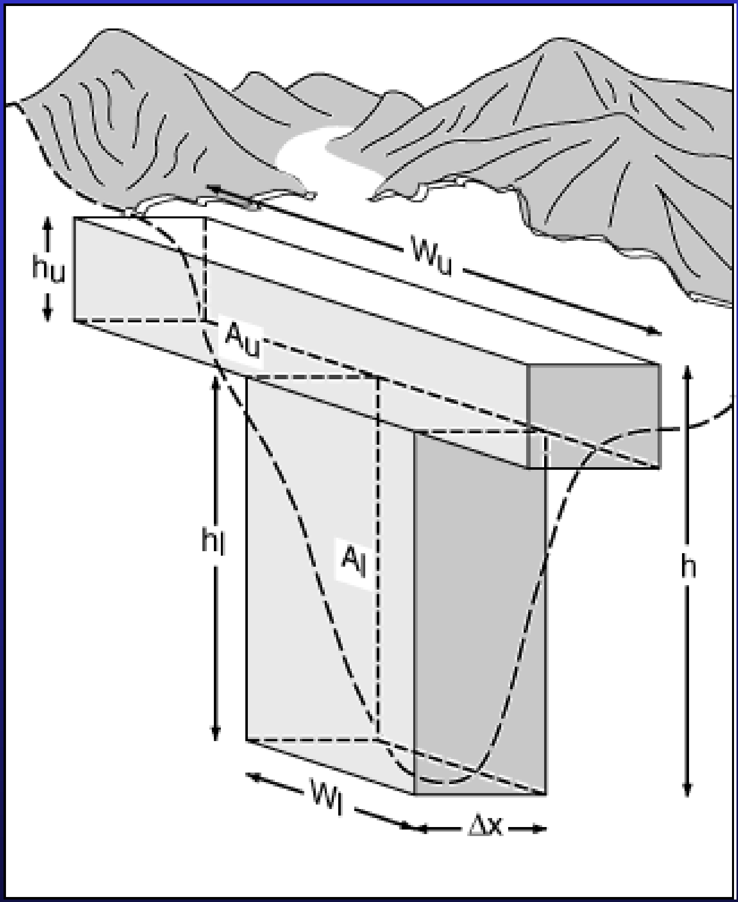
USGS

Calibration to bathymetric change

- Model calibrated to bathymetric change, not SSC
- Bathymetric change is goal of sediment budget and PCB modeling
- SFO experience
- Tetra Tech and USGS bathymetric change and SSC results differ: need to check

Lower segment height

- Short segment 0.29 m tall (box 3)
- Bottom SSC data 0.9 m above bottom
- Lower segments in Lower South Bay only 2.5% of volume: smaller mass error



USGS

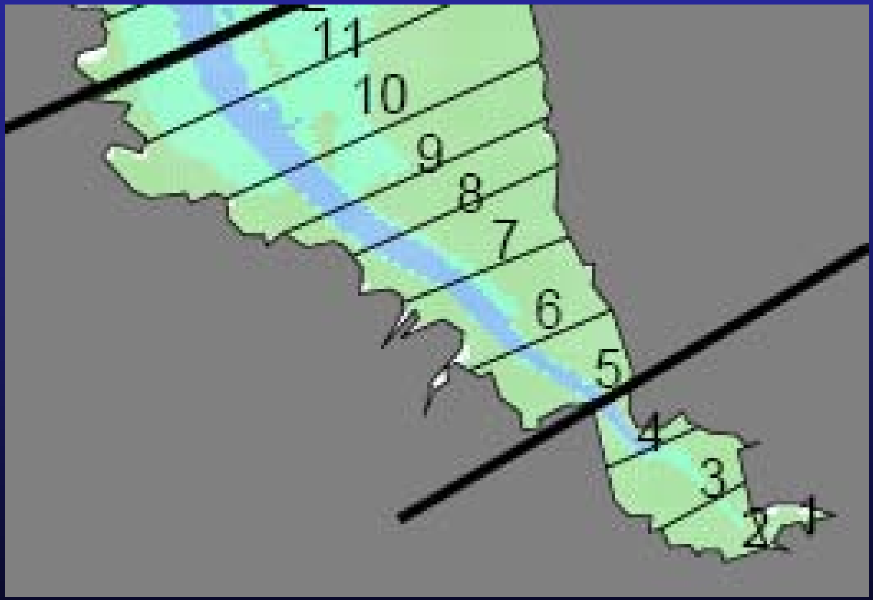
Lower South Bay salt calibration

- UP salinity model calibrated with Dumbarton Bridge data
- If longitudinal mixing is underestimated: SSC must be greater

USGS

Lateral averaging

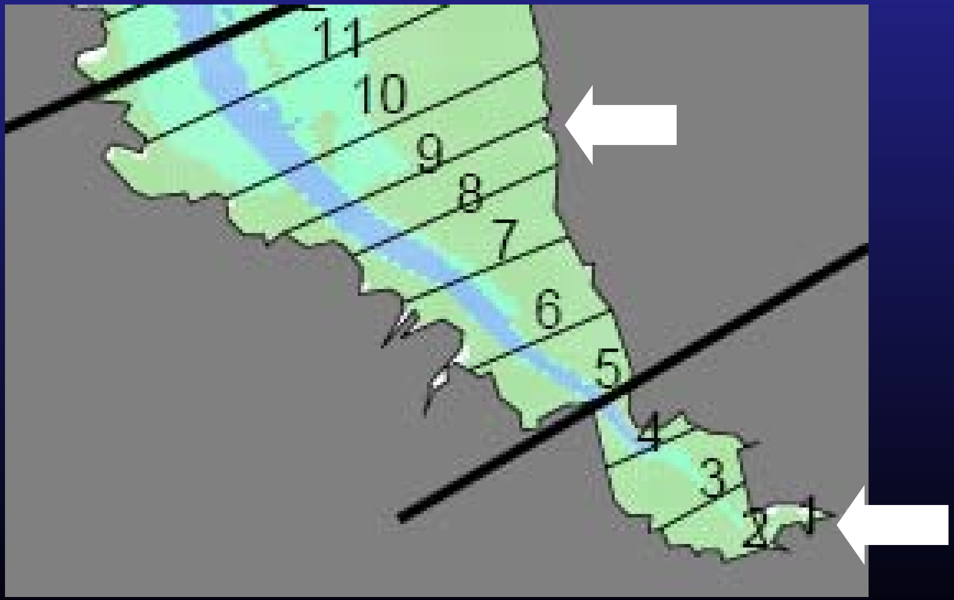
- Typically SSC greater on shoals
- Well-mixed boxes
- Too much sediment in channel



USGS

Lower South Bay tributary loads

- Lateral averaging and few segments cause tributary loads to spread too quickly
- Too much sediment in channel
- Improvement of one-box model



Geomorphic Modeling

- Uncertainty of tributary loads is perhaps 25%, uncertainty of any model will be greater
- Model provides a constrained estimate of bathymetric change
- Multi-dimensional models of Suisun and San Pablo Bays to be developed

USGS

CEP Review

- Reviewing code, rerunning model, checking all output unusual if not unprecedented
- Good for CEP, USGS, SFEI, and the Bay

USGS

Heidel, Katherine -- Tt, Inc.

From: John J Oram [joram@sfei.org]
Sent: Monday, August 15, 2005 12:34 PM
To: Tom Grieb; Mills, Bill -- Tt, Inc.; Heidel, Katherine
Cc: Andy Gunther; David H Schoellhamer
Subject: Re: Tetra Tech review of Multi-Box model

Bill, Katherine, and Tom,

TetraTech's testing is well formulated and the results are presented clearly. I appreciate the time and effort put into this work. Here are my specific comments are:

1) (page 21) - I need to update the SFEI report to include the latest sediment transport equations. This will be done as part of the next report.

2) (pages 26-27) - I can make a more detailed presentation of the sediment mixing equations in the next report. Regarding whether or not I think the change in profiles over 20yrs is reasonable... A purely diffusional timescale to move 50cm into the sediment profile is on the order of 30-35 years (given Db~70cm2/yr). Add deposition (which it appears like this core represents) and the mass could move more quickly.

3) Input Data (pages 29-40) - The Delta flow rates used in the forecast were obtained directly from Noah Knowles. They are results of nested models. They do not represent climatology of Delta outflow. Forecast Freeport SSC is calculated as a function of Delta flow, using the hindcast as a rating curve. Both SSC and Delta flow do lack the magnitude of variability seen in the hindcast, as do many other inputs which are less influential (precip, evap). We certainly can rethink how to generate Delta flow and SSC, though the use of results from Knowles and Cayan has an advantage in that the results are published. I think uncertainty analysis can help us decide how much energy to put into this. As for the effect of sea level rise on tidal flushing, that is a project in its own. I would expect the overall rise and fall of the tides to remain very similar but the tidal prism would change (likely increase). Some good GIS work could tell us how the tidal prism will changed, then we could adjust the box volumes or tidal range accordingly and rerun the model to see the changes on PCB recovery. This is an interesting analysis.

4) Model Initialization (pages 42-44) - I agree there are issues with initialization in both the hindcast and the forecast. The hindcast represents a very different problem, as it involves model spin-up. We can change the start date for the hindcast model. However, it is currently calibrated so that net sedimentation during 1951-1983 matches observations (if I remember correctly). It may be best to start PCBs much later, maybe in the 90s, according to existing field data and then see how they get redistributed. I don't see the forecast as having the same spin-up issues. The spin-up problems seem to be minimized when the model is initialized with box volumes equal to those at the end of the hindcast.

5) pages 46-53 : Dave Schoellhamer has discussed how to examine the ssc comparisons. When taken in context the comparisons are not as bad as they first appear.

6) net volume change (pg 57) : the calculations are incorrect. I have discussed this with Katherine. She will make new calculations and report those results.

That is all for now. Good work. Let me know if you have any further questions.
-John

Andy Gunther wrote:

>Attached is a PDF version of a powerpoint presentation that summarizes the
>findings from Tetra Tech's analysis/testing of the multi-box model pursuant
>to Task 3.1 of the CEP project. I think Tom, Bill, and their staff have done
>an excellent job on this, and it represents a rigorous and important step in
>model development.
>
>Please take a look at this document, and provide any comments to me (or just
>cc the whole group). Key questions are:
>
>1. Do you disagree with any findings/recommendations?
>2. Do you have comments on any aspect of the presentation (see where
>"Comments?" has been included in green).
>3. Thoughts on next steps
>
>Regarding next steps, I propose the following.
>
>1. Tt will incorporate any comments/suggestions from our group.
>2. Tt will prepare a short "executive summary" of key findings and
>recommendations. (Highlighted in this summary will be findings and
>recommendations that should be considered in conducting the core sampling
>program). This summary, plus the PDF of the powerpoint, will be distributed
>to the CFWG for their comments.
>3. CFWG comments will be appended to the document, and it will be delivered
>to the TC.
>4. After TC review, document will be revised and Task 3.1 will be complete.
>
>In the meantime, I hope to have a revised draft of the sediment sampling
>plan by the end of the week, with an updated budget.
>
>We need to revise the Detailed Scope of Work for the project to reflect
>recent budget/schedule changes, and also to reflect updated thinking on the
>cost of the field sampling, what analytes will be included in core
>chemistry, and what the "next pollutant" to be modeled will be.
>
>Andy
>-----
>Andrew J. Gunther, Ph.D.
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>

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John J Oram, PhD
Environmental Scientist
San Francisco Estuary Institute

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Web: www.sfei.org

From: Heidel, Katherine -- Tt, Inc.
Sent: Monday, August 15, 2005 12:24 PM
To: Mills, Bill -- Tt, Inc.
Subject: FW: Multibox model

-----Original Message-----
From: John J Oram [mailto:joram@sfei.org]
Sent: Monday, August 15, 2005 11:23 AM
To: Heidel, Katherine -- Tt, Inc.
Subject: Re: Multibox model

Hi Katherine,

Sorry for the delay on this ...

Here is how net volume change should be calculated. The way you described is a water-side calculation and it assumes the change in box volume is 1:1 with change in sediment mass. This is not true for the upper layers where the sediments only cover part of the box area (some of the box area is actually the boundary with the lower layer). The method below uses the netmass variable, and is a sediment-side approach. Results should be better.

```
%%-----------------------------------------------------------------
fname   = '../outputs/modelout.1.nc';  % hindcast
t       = read_netcdf(fname,'time') + julian(1900,1,1);
beddens = read_netcdf(fname,'beddens')';  % g/m3
netmass = read_netcdf(fname,'netmass').*1000;  % g
netvol  = netmass ./ repmat(beddens,[length(t),1,2]);  % m3

%%%%% Pick one of these sections ...
%% Suisun
 tdx = find( t>=julian(1942,1,1) & t<=julian(1990,12,31) );
 idx = 29:41;
%% South Bay
 tdx = find( t>=julian(1956,1,1) & t<=julian(1983,12,31) );
 idx = 1:14;
%% Lower South Bay
 tdx = find( t>=julian(1942,1,1) & t<=julian(1990,12,31) );
 idx = 1:4;
%% San Pablo Bay
 tdx = find( t>=julian(1951,1,1) & t<=julian(1983,12,31) );
 idx = 23:28;


%%% Do the calculation for net volume change
dv = sum(netvol(:,idx,:),3);
dv = sum(dv,2);
dv = integral(dv,1);
dv = dv(tdx);
dv = dv(1) - dv(end)
%%-----------------------------------------------------------------
```

I placed the latest results (modelout.1.nc and modelout.2.nc) on our ftp site.

ftp.sfei.org
login = anonymous
pass = your email

-John

Heidel, Katherine -- Tt, Inc. wrote:

> John,
>
> We are working on creating a report of our findings (basically the presentation we sent out with more text to describe the figures). We'd like to re-do the 1:1 comparison plots. The figures in the presentation were completed before the bug was found and corrected. Can you post your base case hindcast and forecast to your ftp site so I can recreate these plots?
>
> Also, I wanted to check in with you on your status with the volume comparisons. Do you have everything you need from us at this point?
>
> Thanks,
> Katherine

--

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From: David H Schoellhamer [dschoell@usgs.gov]
Sent: Tuesday, August 16, 2005 11:46 AM
To: Andy Gunther; Bill.Mills@tetratech.com
Cc: joram@sfei.org; mlionber@usgs.gov
Subject: Re: FW: Draft PCB model review

Bill-

Andy sent you my CEP Powerpoint, which can serve as my response to the SSC problems. We have added the missing evaporation data. Thank you for your helpful comments, Dave

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Information on Suspended-sediment transport in San Francisco Bay and Delta
Continuous Monitoring Data from San Francisco Bay
USGS Publications Related to Continuous Monitoring of San Francisco Bay

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Andy Gunther <gunther@amarine.com>

08/15/2005 09:05 AM

To David H Schoellhamer <dschoell@usgs.gov>, John J Oram <joram@sfei.org>
cc
Subject FW: Draft PCB model review

Gents:

Tetra Tech will be preparing their draft report based on the enclosed Powerpoint file, which was forwarded to you earlier. Please forward any comments you have to Bill Mills (cc me) as soon as possible. (Dave; I already forwarded to Mills the powerpoint file from your August presentation to the TC).

Thanks.

Andy

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------ Forwarded Message
From: "Mills, Bill -- Tt, Inc." <Bill.Mills@tetratech.com>
Date: Fri, 29 Jul 2005 13:57:40 -0700
To: 'Andy Gunther' <gunther@amarine.com>
Subject: Draft PCB model review

Andy
Here is the draft review. I am sending it to you, assuming you want to distribute it.

Thanks. Bill

-----Original Message-----
From: Andy Gunther [mailto:gunther@amarine.com]
Sent: Tuesday, July 26, 2005 11:48 AM
To: Mills, Bill -- Tt, Inc.
Subject: Re: SSC at other Bay stations

Thanks...I should have figured both of those out myself!

Powerpoint presentation (we are going to send a pdf actually) and Tom Mumley

-----Original Message-----
From: Andy Gunther [mailto:gunther@amarine.com]
Sent: Tuesday, July 26, 2005 10:02 AM
To: Mills, Bill -- Tt, Inc.
Subject: Re: SSC at other Bay stations

Thanks. What does PPT stand for, and who is Tom M.?

Andy
Yes, we are incorporating some now. As you know, we(Tt) agreed at the last meeting (you were on the phone, so I assume you knew this) to send out a PPT of the work we have completed- Tom M. thought this should be done to disseminate our results as quickly as possible. That PPT will contain comparisons of SSC at other locations in the Bay. Since this work will be available before the 8/3 meeting, I think Dave S. should be aware of our findings before that meeting so he is not surprised.

We plan on sending the PPT to you first (and SFEI?), and then once you are happy with it, I assume you would want to send it around to others.

Bill

-----Original Message-----
From: Andy Gunther [mailto:gunther@amarine.com]
Sent: Tuesday, July 26, 2005 9:17 AM
To: Mills, Bill -- Tt, Inc.; Tom Grieb
Subject: SSC at other Bay stations

Bill/Tom:

I was wondering if you have had a chance to make some other model runs to compare predicted SSC to measured at other Bay locations. Dave Schoellhammer has agreed to drop by the TC meeting on 8/3 to discuss this issue further. He will be first on the agenda (1:15 or so), and it might be useful for one of you to hear his presentation and the Q&A.

Andy

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------ End of Forwarded Message[attachment "MBM_Review_Jul 28_2005.v3.pdf" deleted by David H Schoellhamer/WRD/USGS/DOI]