USEPA National Watershed Protection Program
New York/New Jersey Harbor Estuary Program

SEDIMENT AREA LOADING COMPONENT ANALYSIS AND SPREADSHEET TOOL DEVELOPMENT INTERPRETATIVE TECHNICAL MEMORANDUM

Task 3f (Phase 1) Contractor Deliverable

TECHNICAL SUPPORT FOR NY/NJ HARBOR ESTUARY PROGRAM USEPA REGION 2 TOXICS TMDL MODEL DEVELOPMENT

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1.0 INTRODUCTION

The previously developed CARP models were applied to evaluate three areas of the New York New Jersey Harbor sediment bed as unit response loading source components. Two PCB homologs, tetra-CB and hexa-CB were evaluated per EPA's specification. In total, six thirty-two year simulations of the CARP model were performed and the results of the model simulations were stored within previously developed CARP spreadsheet tools so that EPA and the States could perform "what if?" calculations.

The sediment bed areas, as shown in Figure 1, were identified by EPA as:

- Upper Bay (bounded by the Kill van Kull and Newark Bay confluence and the George Washington, Verranzano Narrows, and Brooklyn Bridges)
- Hudson River (bounded by the George Washington Bridge, Spuyten Duyvil, and Troy Dam)
- Arthur Kill

In the loading source component analysis, each of the sediment bed areas was activated in the model on a stand-alone basis to isolate the impacts of that sediment bed area on contaminant concentrations in water, sediment, and biota throughout the system over thirty-two years of simulation. The spreadsheet tools store the results at the end of the thirty-two years of simulation. The long simulation time allows for a response of the system to a long-term exposure to the contamination in the sediment bed areas now.

The role of each of the sediment bed areas is expected to be more apparent for hexa-CB, a higher chlorinated homolog, than for tetra-CB. This is consistent with the fact that higher chlorinated compounds are more strongly associated with particles and therefore have greater residence time in the system due to estuarine trapping, decreased volatilization and smaller effects of other diffusive exchange processes. On the other hand, the current loadings of tetra-CB are generally greater than those of hexa-CB, producing potentially greater concentrations in the bed, water column, and biota. For this reason, the role of tetra-CB from sediment bed areas may be greater than hexa-CB.

2.0 RESULTS OF THE ANALYSIS

The results of the analysis are fully presented in the spreadsheet tools delivered to EPA. Results are both tabulated and graphically displayed within the spreadsheet tools. A narrative discussion is provided here for each of the three sediment areas as well as that portion of the sediment bed defined as "All Other Areas." "All Other Areas" refers to those portions of the sediment bed outside of the Passaic River (evaluated previously), Newark Bay (evaluated previously), Upper Bay sediment area, Hudson River sediment area, and Arthur Kill.

2.1.1 Hexa-CB Sediment Responses Due to Upper Bay Area Sediments

For hexa-CB, concentrations in the sediments of the Upper Bay sediment area now will spread into surficial sediment concentrations in other sediment areas in the future based on the CARP model calculations stored in the spreadsheet tools. The model results suggest that the now in-place sediment contamination from the Upper Bay sediment area has its greatest impact on future concentrations of hexa-CB in the Kill van Kull. 15% of future hexa-CB concentrations in the Kill van Kull sediments will be from the Upper Bay sediment area. Surficial sediments in the Upper Bay are expected to be rapidly replaced by sediments migrating in from external sediment areas (52%) and by deposition of on-going current sources (37%) with only 11% of expected future hexa-CB concentrations in the Upper Bay sediment area due to sediments currently in-place there. The management implications are that while a remedy for Upper Bay sediments will have at most a 15% impact on hexa-CB concentrations in the Upper Bay and other Harbor sediments, remediation of sediments in other Harbor areas will have larger (i.e., 52% of expected future concentrations) impacts on the Upper Bay sediment area.

2.1.2 Hexa-CB Water Column Responses Due to Upper Bay Area Sediments

Hexa-CB results in the water column are similar to those described for the sediment bed in terms of spatial patterns of response. Hexa-CB from the Upper Bay sediment area today is projected to contribute enough to water column concentrations of hexa-CB in the future to be entirely responsible for violations of the human health water quality standards applicable to the summation of ten PCB homologs. Expected future concentrations of hexa-CB in the water column due to sediment concentrations from the Upper Bay sediment area today range from effectively 0 ng/L in the Upper Hudson to 0.0343 ng/L in the Arthur Kill. The water quality standards for all PCBs, not just hexa-CB, are 0.001 ng/L in New York and 0.064 ng/L in New Jersey.

2.1.3 Tetra-CB Sediment Responses Due to Upper Bay Area Sediments

For tetra-CB, concentrations in the sediments of the Upper Bay sediment area now will spread into surficial sediment concentrations in other sediment areas in the future based on the CARP model calculations stored in the spreadsheet tools. The model results suggest that the now in-place sediment contamination from the Upper Bay sediment area has its greatest impact on future concentrations of tetra-CB in the Kill van Kull. 9% of future tetra-CB concentrations in the Kill van Kull sediments will be from the Upper Bay sediment area. Surficial sediments in the Upper Bay are expected to be rapidly replaced by sediments migrating in from external sediment areas (45%) and by deposition of on-going current sources (49%) with only 6% of expected future tetra-CB concentrations in the Upper Bay sediment area due to sediments currently in-place there. The management implications are that while a remedy for Upper Bay sediments will have at most a 9% impact on tetra-CB concentrations in the Upper Bay and other Harbor sediments, remedy of sediments in other Harbor areas will have larger (i.e., 45% of expected future concentrations) impacts on the Upper Bay sediment area.

2.1.4 Tetra-CB Water Column Responses Due to Upper Bay Area Sediments

Tetra-CB results in the water column are similar to those described for the sediment bed in terms of spatial patterns of response. Tetra-CB from the Upper Bay sediment area today is projected to contribute enough to water column concentrations of tetra-CB in the future to be entirely responsible for violations of the human health water quality standards applicable to the summation of ten PCB homologs. Expected future concentrations of tetra-CB in the water column due to sediment concentrations from the Upper Bay sediment area today will range from effectively 0 ng/L in the Upper Hudson to 0.0514 ng/L in the Arthur Kill. The water quality standards for all PCBs, not just hexa-CB, are 0.001 ng/L in New York and 0.064 ng/L in New Jersey.

2.1.5 Hexa-CB Sediment Responses Due to Hudson River Area Sediments

For hexa-CB, concentrations in the sediments of the Hudson River sediment area now will contribute to surficial sediment concentrations in the future based on the CARP model calculations stored in the spreadsheet tools. The model results suggest that the now in-place sediment contamination from the Hudson River sediment area has its greatest impact on future concentrations of hexa-CB in the Haverstraw Bay to above the confluence with the Harlem River reach of the Hudson River (miles 24.6 to 13.9). Hexa-CB in the Hudson River sediment area today is expected to account for about 37% of future hexa-CB concentrations in the mile 24.6 to 13.9 reach of the Hudson River. Other places that sediments from the Hudson River area will contribute hexa-CB to in the future include: the Harlem and Lower East Rivers, portions of the Hudson River, the Upper Bay, the Kill van Kull, Newark Bay, and the Arthur Kill. The implication is that a remedy of the Hudson River sediment area as defined by EPA will also somewhat improve future sediment concentrations of hexa-CB in the Harlem and Lower East Rivers, portions of the Hudson River, the Upper Bay, the Kill van Kull, Newark Bay, and the Arthur Kill. Conversely, this also implies that if sediment remedies were initiated in the Harlem and Lower East Rivers, portions of the Hudson River, the Upper Bay, the Kill van Kull, Newark Bay, and the Arthur Kill, hexa-CB from the Hudson River sediment area would contribute to future re-contamination of these locations.

2.1.6 Hexa-CB Water Column Responses Due to Hudson River Area Sediments

Hexa-CB results in the water column are similar to those described for the sediment bed in terms of spatial patterns of response. In addition, the waters of the Hackensack and Raritan Rivers and Raritan Bay will be noticeably impacted for hexa-CB in the future by the Hudson River sediment area. Hexa-CB from the Hudson River sediment area today is projected to contribute enough to water column concentrations of hexa-CB in the future to be entirely responsible for violations of the human health water quality standards applicable to the summation of ten PCB homologs. Expected future concentrations of hexa-CB in the water column due to sediment concentrations from the Hudson River sediment area today range from 0.0002 ng/L in the Bight to 0.4383 ng/L in the Hudson River itself. The water quality standards for all PCBs, not just hexa-CB, are 0.001 ng/L in New York and 0.064 ng/L in New Jersey.

2.1.7 Tetra-CB Sediment Responses Due to Hudson River Area Sediments

For tetra-CB, concentrations in the sediments of the Hudson River sediment area now will contribute to surficial sediment concentrations in the future based on the CARP model calculations stored in the spreadsheet tools. The model results suggest that the now in-place sediment contamination from the Hudson River sediment area has its greatest impact on future concentrations of tetra-CB in the Haverstraw Bay to above the confluence with the Harlem River reach of the Hudson River (miles 24.6 to 13.9). Tetra-CB in the Hudson River sediment area today is expected to account for about 38% of future tetra-CB concentrations in the mile 24.6 to 13.9 reach of the Hudson River. Other places that sediments from the Hudson River area will contribute tetra-CB to in the future include: portions of the Hudson, the Upper Bay, the Lower Bay, the Kill van Kull, Newark Bay, Hackensack River, Passaic River, the Arthur Kill, the Raritan River/Bay, the Harlem and Lower East Rivers, the Upper East River and Long Island Sound, Jamaica Bay, and the Bight Apex. The implication is that a remedy of the Hudson River sediment area as defined by EPA will also somewhat improve future sediment concentrations of tetra-CB in the portions of the Hudson River, the Upper Bay, the Lower Bay, the Kill van Kull, Newark Bay, Hackensack River, Passaic River, the Arthur Kill, the Raritan River/Bay, the Harlem and Lower East Rivers, the Upper East River and Long Island Sound, Jamaica Bay, and the Bight Apex. Conversely, this also implies that if sediment remedies were initiated in the portions of the Hudson River, the Upper Bay, the Lower Bay, the Kill van Kull, Newark Bay, Hackensack River, Passaic River, the Arthur Kill, the Raritan River/Bay, the Harlem and Lower East Rivers, the Upper East River and Long Island Sound, Jamaica Bay, and the Bight Apex, tetra-CB from the Hudson River sediment area would contribute to future re-contamination of these locations.

2.1.8 Tetra-CB Water Column Responses Due to Hudson River Area Sediments

Tetra-CB results in the water column are similar to those described for the sediment bed in terms of spatial patterns of response. Tetra-CB from the Hudson River sediment area today is projected to contribute enough to water column concentrations of tetra-CB in the future to be entirely responsible for violations of the human health water quality standards applicable to the summation of ten PCB homologs. Expected future concentrations of tetra-CB in the water column due to sediment concentrations from the Hudson River sediment area today range from 0.0008 ng/L in the extreme eastern waters of Long Island Sound to 1.3434 ng/L in the Hudson River itself. The water quality standards for all PCBs, not just tetra-CB, are 0.001 ng/L in New York and 0.064 ng/L in New Jersey.

2.1.9 Hexa-CB Sediment Responses Due to Arthur Kill Sediments

For hexa-CB, concentrations in the sediments of the Arthur Kill sediment area now will contribute very little to surficial sediment concentrations in the future based on the CARP model calculations stored in the spreadsheet tools. The model results suggest that the now in-place sediment contamination from the Arthur Kill sediment area has its greatest impact on future concentrations of hexa-CB in the Arthur Kill itself. Hexa-CB in the Arthur Kill sediment area today is expected to account for about 16% of future hexa-CB concentrations in the Arthur Kill. These results are indicative that surficial sediments in the Kills are rapidly replaced by sediments migrating in from other sediment areas (49%) and by deposition of on-going current sources (35%). The management implications are that while a remedy of Arthur Kill sediments will have little impact on hexa-CB concentrations in Arthur Kill and other Harbor sediments, remedy of sediments in other Harbor areas will have large impacts on the Arthur Kill.

2.1.10 Hexa-CB Water Column Responses Due to Arthur Kill Area Sediments

Hexa-CB results in the water column are similar to those described for the sediment bed in terms of spatial patterns of response. Hexa-CB from the Arthur Kill sediment area today is projected to contribute enough to water column concentrations of hexa-CB in the future to be entirely responsible for violations of the human health water quality standards applicable to the summation of ten PCB homologs. Expected future concentrations of hexa-CB in the water column due to sediment concentrations from the Arthur Kill sediment area today range from effectively 0 ng/L in the Bight to 0.0359 ng/L in the Arthur Kill itself. The water quality standards for all PCBs, not just hexa-CB, are 0.001 ng/L in New York and 0.064 ng/L in New Jersey.

2.1.11 Tetra-CB Sediment Responses Due to Arthur Kill Sediments

For tetra-CB, concentrations in the sediments of the Arthur Kill sediment area now will contribute very little to surficial sediment concentrations in the future based on the CARP model calculations stored in the spreadsheet tools. The model results suggest that the now in-place sediment contamination from the Arthur Kill sediment area has its greatest impact on future concentrations of tetra-CB in the Arthur Kill itself. Tetra-CB in the Arthur Kill sediment area today is expected to account for about 7.4% of future tetra-CB concentrations in the Arthur Kill. These results are indicative that surficial sediments in the Kills are rapidly replaced by sediments migrating in from other sediment areas (54.6%) and by deposition of on-going current sources (38%). The management implications are that while a remedy for Arthur Kill sediments will have little impact on tetra-CB concentrations in Arthur Kill and other Harbor sediments, remedy of sediments in other Harbor areas will have large impacts on the Arthur Kill.

2.1.12 Tetra-CB Water Column Responses Due to Arthur Kill Area Sediments

Tetra-CB results in the water column are similar to those described for the sediment bed in terms of confined spatial patterns of response. Tetra-CB from the Arthur Kill sediment area today is projected to contribute enough to water column concentrations of tetra-CB in the future to be entirely responsible for violations of the human health water quality standards applicable to the summation of ten PCB homologs. Expected future concentrations of tetra-CB in the water column due to sediment concentrations from the Arthur Kill sediment area today range from effectively 0 ng/L in the Upper Hudson to 0.04 ng/L in the Arthur Kill itself. The water quality standards for all PCBs, not just tetra-CB, are 0.001 ng/L in New York and 0.064 ng/L in New Jersey.

2.2 RESPONSES TO "ALL OTHER" AREA SEDIMENTS

While the CARP model results stored in the spreadsheet tools identify the expected future concentrations of tetra-CB and hexa-CB in water, sediment, and biota throughout the Harbor due to current sediments specifically from each of the Passaic River, Newark Bay, the Arthur Kill, the Upper Bay Area, and the Hudson River Area, the now available CARP model results consider tetra-CB and hexa-CB from the sediments of the Hackensack River, the Raritan River/Bay, the East River, Jamaica Bay, the Bight, and the Sound as a single source, "All Other Sediments." Where "All Other Sediments" contribute significantly to expected future ambient concentrations of tetra-CB and hexa-CB, the EPA specifically requested that HydroQual offer an opinion as to the dominant portion of "All Other Sediments" responsible.

Based on CARP model results, "All Other Sediments" are expected to be an important future source in a number of regions as tabulated in Table 1. In each case the like contributors are also noted.

Table 1. Identification of locations where "All Other Sediments" are expected to contribute to tetra-CB and hexa-CB future contamination and likely drivers.

Reach Impacted by "All Other Sediments"	Probable Identification of "All Other Sediments"
Lower Hudson River	East & Harlem Rivers sediments
Upper Bay	East River sediments
Lower Bay	Lower Bay sediments East River sediments Jamaica Bay sediments Raritan Bay sediments
Kill van Kull	East River sediments
Newark Bay	Hackensack River sediments East River sediments
Hackensack River	Hackensack River sediments
Arthur Kill	Hackensack River sediments East River sediments Raritan River sediments Raritan Bay sediments
Raritan Bay	Raritan Bay sediments Raritan River sediments Lower Bay sediments Jamaica Bay sediments
Raritan River	Raritan Bay sediments Raritan River sediments
Harlem & Lower East Rivers	East & Harlem Rivers sediments Long Island Sound sediments
Upper East River/Western Long Island Sound	Long Island Sound sediments East River sediments
Eastern long Island Sound	Eastern Long Island Sound sediments
Bight/Ocean	Bight sediments Hackensack River sediments East & Harlem Rivers sediments Raritan River sediments Raritan Bay sediments Lower Bay sediments Jamaica Bay sediments

2.3 BIOTA RESPONSES DUE TO ALL AREA SEDIMENTS

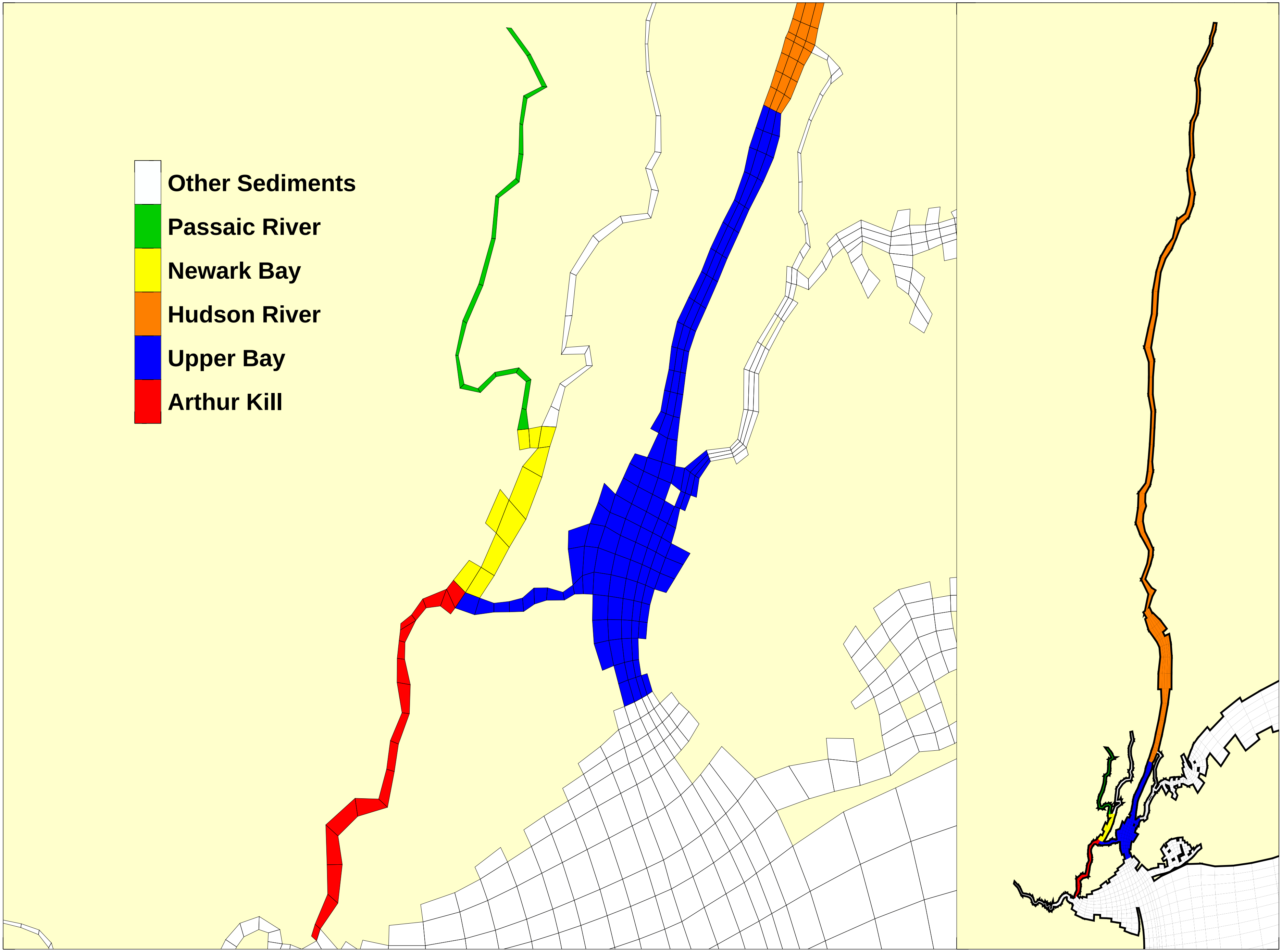
The spreadsheet tools include results for a number for different benthic and pelagic organisms. Since these results were calculated by applying bioaccumulation factors (BAFs) to water column results and biota-sediment accumulation factors (BSAFs) to sediment results, further discussion of the biota responses beyond the discussions for sediment and water column responses are not warranted. By virtue of the BAFs and BSAFs, biota responses will track sediment and water column responses.

3.0 FURTHER INFORMATION NEEDS TO CHARACTERIZE SEDIMENT AREA INFLUENCES MORE COMPLETELY

Drawing final management conclusion about exactly where to remedy sediments to achieve the greatest benefits requires a consideration of additional contaminants beyond tetra-CB and hexa-CB. Other contaminants will have different spatial patterns of current and historical source inputs. Candidate contaminants might include other PCB homologs, dioxin/furan congeners, or DDT and its metabolites. Benzo(a)pyrene and chlordane are not suggested for this purpose since previous results suggest their future concentrations are controlled more by on-going sources than by in-place sediments. In addition, the contribution of sediments from the East River, which have relatively high tetra-CB and hexa-CB current concentrations, to future concentrations in other sediment areas is a significant unknown. The role of East River sediments could be addressed by conducting additional unit response loading source component simulations with the CARP model and further expanding the CARP model spreadsheet tools.

4.0 OVERALL CONCLUSIONS

Of the three sediment areas evaluated as sources of tetra-CB and hexa-CB, the Hudson River area sediments have the greatest impacts. This conclusion is consistent with the large geographic size of the Hudson River sediment area as defined by EPA and the proximity of this sediment area to a large ongoing PCB source (i.e., the Upper Hudson River loading over Troy Dam). While the Arthur Kill sediment area doesn't contribute tetra-CB and hexa-CB significantly to other areas, it is the recipient of tetra-CB and hexa-CB from both other sediment areas and on-going current loadings. The small size of the Arthur Kill sediment area relative to the much larger size of sediment areas with net water circulation directed toward the Arthur Kill (i.e., the Hudson River, the East River, the Upper Bay, the Kill van Kull, the Passaic River, etc) support this finding. The Upper Bay sediment area will be both dispersive of the tetra-CB and hexa-CB currently contaminating its sediments in the future and will receive future inputs of tetra-CB and hexa-CB from both other external sediment areas and on-going loadings. In this sense, the Upper Bay sediment area is serving as a temporary storage location for tetra-CB and hexa-CB. In all three sediment areas evaluated, burial of tetra-CB and hexa-CB is another mechanism active in the calculations by which contaminant concentrations in surficial sediments will decrease in the future. The East River might be an important source of hexa-CB and tetra-CB contamination to a number of sediment areas in the future.



EPA Tetra-CB and Hexa-CB Sediment Component Runs, Sediment Regions