PRELIMINARY MODEL CALIBRATION REPORT

REVISED APPENDIX B

MATHEMATICAL MODELING OF PCB FATE AND TRANSPORT FOR HUDSON RIVER PCB REASSESSMENT RI/FS

CURRENT MODELING WORKPLAN

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1. LIMNO-TECH, INC.

1.1 BACKGROUND

In December 1989 USEPA decided to reassess the No Action decision for Hudson River sediments. This reassessment consists of three phases: Interim Characterization and Evaluation (Phase 1); Further Site Characterization and Analysis (Phase 2); and Feasibility Study (Phase 3). Limno-Tech, Inc. (LTI) was selected by TAMS to provide services for mathematical modeling activities identified in the Phase 2 Work Plan.

1.2 OBJECTIVES

The objectives of the mathematical modeling studies being conducted to support this Hudson River PCBs Reassessment RI/FS are the following:

1. Predict PCB concentrations in the water column, sediments and fish over long-term time scales in the Upper Hudson River.

2. Estimate the potential for contaminated sediments in Thompson Island Pool (TIP) to become "reactivated" in response to a major flood event.

3. Evaluate and compare predicted responses to continued No Action and various remedial scenarios.

1.3 PROGRESS TO DATE

The Preliminary Model Calibration Report (PMCR) (1996) presents work completed during the first part of the project, in which LTI developed a mass balance model for PCB transport and fate in the Upper Hudson River water column and sediments. This model was used to simulate Total PCBs and five congeners from January 1 through September 30, 1993, corresponding to the Phase 2 water column sampling period. To evaluate resuspension potential in the Thompson Island Pool, LTI also developed and applied a cohesive sediment Depth-of-Scour Model driven by fine scale velocity predictions from application of a two-dimensional hydrodynamic model. Additionally, LTI applied a previously-developed model (Thomann et al. 1989, 1991) for PCB transport and fate in the Lower Hudson River which also included bioaccumulation in striped bass. The Cadmus Group, Inc. (Cadmus) developed statistical models relating PCB concentrations in water and sediments to fish body burdens in the Upper and Lower Hudson Rivers. Cadmus also conducted several important data analysis activities including sediment PCB mass estimates through kriging analysis, estimation of long-term flows and PCB loadings to the Upper Hudson River, determination of PCB phase partitioning relationships and investigation of relationships among congener groups, total PCBs and Aroclors in sediments and the water column. Finally, Menzie-Cura & Associates (MCA) developed a probabilistic bioaccumulation model to describe exposure-body burden relationships in fish using a mechanistic approach. MCA has also explored the use of

several parallel modeling approaches including use of the Gobas model as well as several time-varying bioenergetic models.

Pursuant to a decision by USEPA, TAMS Consultants, Inc. has directed LTI to discontinue all work on the Lower Hudson River model. The reason is that the Lower Hudson River model is currently being updated by Drs. Robert Thomann and Kevin Farley as part of a separate project. Upon completion of this work, USEPA will review the updated model and decide how it should be used to assess the impacts of PCB loads from the Upper Hudson River on the lower river and estuary.

It should also be noted that work previously conducted by the Cadmus Group, Inc. is now being conducted by Tetra Tech, Inc.

1.4 MODELING TASKS

The following task descriptions provide an overview of the current workplan LTI is pursuing toward meeting the project objectives of the Hudson River PCBs Reassessment RI/FS.

1.5 BASELINE MODELING

1.5.1 Upper Hudson River Modeling.

Re-segmentation of the HUDTOX model

The HUDTOX model will be re-segmented to develop a more finely-resolved spatial segmentation grid for the TIP and downstream reaches. The refined grid will be two-dimensional in the water column in TIP and one-dimensional in the water column downstream of TIP. The sediment layer segmentation will be three-dimensional throughout, with most water column segments overlying cohesive and non-cohesive sediment segments. This more finely-resolved grid will distinguish between cohesive and non-cohesive sediment areas as well as between regions with differing levels of PCB contamination. In the TIP, the two-dimensional water column segmentation grid will be applied to also reflect the effects of bathymetry on water column velocities and sediment-water shear stresses. The re-segmentation of TIP will be based on a detailed characterization of TIP sediments in terms of particle type, particle size distributions, clay content, porosity, and total PCB concentration, as well as velocity fields from a two-dimensional hydrodynamic model. Re-segmentation of the portion of the HUDTOX model between Thompson Island Dam and Federal Dam will be based on an assessment of sediment types distributions and PCB hot spot locations.

The vertical segmentation of the sediments will be refined throughout the HUDTOX model to provide more accurate description of vertical sediment PCB profiles. Each of the sediment segments will be characterized by a unique set of values for a suite of physical-chemical parameters in the model.

Selection of PCB model state variables

The HUDTOX model calibration will be conducted for a series of simulation periods using a range of PCB forms, including:

1. A parameter termed Tri+ representing the sum of tri- through deca-chlorinated PCB congeners;

2. Total PCBs; and,

3. PCB congeners BZ#4, 28, 52, 90+101 and 138.

The historical Total PCB data for the Upper Hudson River, produced under various investigations, do not represent identical congener groupings due to differences in analytical methods. An analysis of these analytical methods revealed that a parameter identified as Tri+ (sum of tri- through deca-chlorinated congeners) was in common and internally consistent among the different historical data sets. Therefore, model initial conditions, loadings, and calibration targets will be computed for the Tri+ parameter in each data set for use in a long-term calibration of the HUDTOX model.

While Total PCBs are not consistently represented throughout all data sets, samples collected since 1990 by USGS, GE and USEPA do quantify total PCBs in the sediments and water column. The HUDTOX model calibration to the long-term Tri+ parameter simulation will be supplemented by a separate calibration to Total PCBs extending from 1991 through 1997.

The HUDTOX model will also be calibrated to the five PCB congeners listed above over a simulation period from January 1, 1993 through September 30, 1993. Calibration to the five congeners, which represent a range of PCB sorption and volatilization properties, will provide better understanding of the relative importance of different environmental processes on PCB dynamics.

Calibration of revised HUDTOX model to Spring 1994 and 1997 high-flow surveys.

Calibration of the HUDTOX model to the Spring 1994 and Spring 1997 high-flow surveys during which high-frequency data on solids were collected is intended to reduce uncertainties in specification of solids settling and resuspension parameters in the model. The model will be calibrated to daily suspended solids data for April 1994, the peak flow period for the year. The maximum flow during this month corresponded to approximately a 5-year flood and represents the most useful solids data available for calibrating solids dynamics at high flow. Additional high-frequency, high-flow suspended solids data has been collected by GE during the Spring of 1997, although at fewer stations than in the April 1994 survey. These data will be used to validate the calibration of the solids settling and resuspension parameterization developed from calibration to the high-frequency April 1994 data.

This effort will also include an assessment of all available flow and suspended solids concentration data for the Upper Hudson River. The purpose of this assessment will be to develop site-specific relationships that can be used to parameterize gross settling and resuspension velocities as

functions of flow or velocity. In TIP, these functions will be driven by flow velocity and/or sediment-water shear stress computations from an application of a two-dimensional hydrodynamic model. In addition, available sediment data for TIP will be used to help parameterize resuspension velocities as functions of segment-specific, physical-chemical properties. These data will include side-scan sonar, measurements of particle sizes and sediment types, data from the EPA 1994 Phase 2 low-resolution coring effort, and sediment characterizations developed from sampling conducted by GE in 1997 for reaches downstream of the Thompson Island Pool.

Long-term hindcasting calibration of revised HUDTOX model to available water column PCB data and the 1984 NYSDEC, 1991 GE, and 1994 USEPA sediment data sets.

The revised HUDTOX model simulating the Tri+ PCB parameter will be calibrated in hindcast mode to available water column and sediment data sets for the period January 1, 1977 through September 30, 1997. The purpose of this task is to reduce prediction uncertainty by ensuring that model output for water column and sediment PCB concentrations in the Upper Hudson River are consistent with observed levels over a two decade time scale (1977-1997). Principal data tasks that must be completed before conducting the long-term hindcasting calibration are determination of external loadings for water, solids and Tri+ at Fort Edward (the upstream boundary of the model domain) and for tributaries.

The existing HUDTOX model calibration presented in the PMCR was conducted for January 1, through September 30, 1993 only, using un-validated Phase 2 monitoring data which did not include results from the Phase 2 low-resolution sediment coring survey. In addition to updating the calibration to the final, validated Phase 2 data, the scientific credibility of the HUDTOX model will be improved through the historical hindcasting calibration for three principal reasons:

1. The revised spatial segmentation grid will better represent horizontal differences in sediment-water interactions as well as provide more accurate description of PCB dynamics in highly contaminated areas;

2. Calibration of the revised HUDTOX model to high-frequency suspended solids data for April 1994 and Spring 1997 will reduce uncertainties in solids settling and resuspension velocities; and,

3. Calibration to long-term observed water column and sediment PCB concentrations will reduce uncertainty associated with the model's ability to describe long-term trends in PCB dynamics in the river.

Sensitivity analyses with revised HUDTOX model.

Model sensitivity evaluations similar to those analyses presented in the PMCR will be conducted with the revised HUDTOX model to one or more of the simulation periods described above. The purpose of this task is to gain a better quantitative understanding of PCB dynamics in the Upper Hudson River and to strengthen the scientific credibility of the overall model calibration. Model parameters to be evaluated using sensitivity analysis will include external solids and PCB loadings,

sediment PCB initial concentrations, solids settling and resuspension velocities, PCB partitioning, PCB pore water concentrations, sediment-water diffusion rates, atmospheric PCB concentrations and volatilization rates, and the potential effects of pore water advection.

Use of calibrated HUDTOX model to estimate impacts of No Action and major floods.

The calibrated HUDTOX model will be used to simulate impacts due to No Action and major flood scenarios. For the No Action scenario, HUDTOX will be run for a decadal-scale simulation period sufficiently long to establish quasi-steady state conditions. Design specifications for this scenario will be determined jointly among EPA, TAMS/Gradient, LTI, Tetra Tech and MCA. In particular, long-term time series must be constructed for hydraulic flows and external loadings of solids and PCBs. Water column and sediment PCB concentrations from this No Action simulation will be delivered to Tetra Tech and MCA for use in their fish body burden models.

Major flood scenarios will include hydrographs corresponding to the high flow events during April 1993, April 1994 and a computed 100-year flood. For each of these flood scenarios, HUDTOX will be run for a seasonal-scale simulation period sufficiently long to estimate perturbations in pre-event water column and sediment PCB concentrations. Water column and sediment PCB concentrations from these flood scenarios will be delivered to Tetra Tech and MCA for use in their fish body burden models.

1.5.2 Thompson Island Pool Depth of Scour Modeling.

Revision of the Thompson Island Pool Depth of Scour Model

The purpose of this task is to develop a more complete representation of potential resuspension of contaminated sediments from TIP in response to major flood events. The existing TIP resuspension model only represents sediment areas consisting of "cohesive" sediment types. Although sediments in these areas are considered to encompass most of the known PCB hot spots in TIP, containing 58 percent of the PCB mass in the pool (in 1984), 42 percent of the PCB mass reservoir as of 1984 was located in larger sediment areas consisting of "non-cohesive" sediment types, thus necessitating a revised modeling approach which includes these sediments.

Using the best available information from the scientific literature, critical shear stresses will be estimated as a function of the physical characteristics and particle size classes on a two-dimensional grid representing the bottom sediments in the TIP. For a flood event with a given maximum flow, applied shear stresses will be estimated for each sediment location using water velocities from the existing fine-scale hydrodynamic model of the TIP. Given this highly-resolved spatial domain of physical-chemical properties and applied shear stresses, solids/PCB masses resuspended and depths of scour will be estimated for cohesive and non-cohesive sediment types. The current state-of-the-art permits a best-estimate of cohesive depth of scour through a probabilistic modeling approach, while the non-cohesive depth of scour estimate will represent an upper bound.

The revised TIP resuspension model will be used to estimate solids and total PCBs resuspended during peak flow events in April 1993, April 1994 and an estimated 100-year flood. For the 1993

and 1994 flow events, cumulative gross resuspension estimates from the TIP resuspension model will be compared with cumulative gross resuspension results from the TIP portion of the revised HUDTOX model. Finally, statistical uncertainty analyses will be conducted to quantify ranges of uncertainty in solids/PCB resuspension estimates as a function of principal model parameters.

Application of revised TIP Depth of Scour model to results from the Phase 2 high-resolution sediment coring effort

The cohesive sediment depth of scour predictions at specific points will be compared to corresponding PCB concentration profiles in finely-segmented sediment cores collected by USEPA as part of the Phase 2 sampling program. This comparison will indicate the likelihood of scouring to the depth of the peak PCB concentration layer during high-flow events.

1.5.3 Ecological Data Tabulation, Statistics and Modeling.

The TAMS team will perform the primary ecological interpretation and modeling aspects of the program. LTI will be providing support to MCA, the primary investigator in this effort. LTI will also provide support for the additional ecological analyses being performed by Tetra Tech. The support LTI will provide is described by the following sub-task description.

Internal review of bioaccumulation models.

Tetra Tech and MCA will continue to develop models relating PCB water column and sediment exposures to PCB body burdens in fish in the Upper and Lower Hudson Rivers. LTI will continue to provide guidance and internal review for these modeling efforts. This will include review of model assumptions, parameterization, calibration/verification and predictive performance/reliability. Emphasis will be placed on confirming that these modeling efforts are designed to provide the best possible answers to the principal questions in the Reassessment RI/FS.

1.5.4 Combined Geochemical and Ecological Data Interpretation and Modeling.

This subtask represents the integration of the various modeling efforts by the TAMS team. In particular, model results provided by LTI will be used by other team members to estimate PCB body burdens in fish using the biological models developed as described above under the No Action and flood event future scenarios to be simulated with the HUDTOX model. The following subtasks describe the LTI technical support related to this integration of the modeling efforts.

Delivery of PCB water column and sediment exposure fields to Tetra Tech and MCA.

The Tetra Tech and MCA fish body burden models must be linked with PCB concentrations in the water column and sediment. These PCB exposure concentrations for forecast simulations will be determined by the LTI transport and fate models for the Upper and Lower Hudson Rivers. LTI will deliver model outputs for PCB exposures to Tetra Tech and MCA for use in the PCB fish body burden models. These PCB exposures will be in the form of daily, weekly or monthly average concentrations for each of the water column and sediment segments in the Upper and Lower

Hudson River transport and fate models. These exposures will correspond to model simulations for the No Action, and major flood scenarios to be simulated with the HUDTOX model. LTI will also provide output of surface sediment concentration trajectories from the model hindcast application for potential use in the calibration of the Tetra Tech bivariate statistical bioaccumulation model, and will provide sediment and water column concentration output from the model hindcast for use in validating the MCA bioaccumulation model.

Phase 2 geochemical, ecological, and modeling review.

LTI will participate in a series of discussions led by TAMS which will be focused on developing an overall perspective of the geochemical, ecological, and modeling aspects of the Phase 2 program. These discussions will be reflected in the summary and conclusions of the Baseline Modeling Report.

2. MENZIE-CURA & ASSOCIATES, INC.

2.1 BACKGROUND

The scope of work described below is part of a team effort involving TAMS Consultants, Limno-Tech, Inc., Tetra Tech, Inc. and Menzie-Cura & Associates, Inc. In response to a proposal submitted in September, 1992, Menzie-Cura & Associates, Inc. (MCA) was selected to provide support on the bioaccumulation component of the overall project. The initial work plan for these activities was provided in the March 24, 1993 Scope of Work document. This scope of work outlines the proposed MCA work plan for the continuing effort on the Hudson River PCB Reassessment RI/FS.

2.2 OBJECTIVES AND RECOMMENDATIONS

The original objectives of the MCA scope of work submitted on March 24, 1993 were as follows:

1. Evaluate and apply quantitative relationships between PCB water and sediment concentrations and fish body burdens in the Upper and Lower Hudson River.

2. Develop and apply a bioaccumulation model to predict fish responses to select remedial alternatives based on predicted sediment and water concentrations from the LTI models.

3. Review and incorporate the bivariate statistical model developed by Cadmus to evaluate fish responses to changing sediment and water concentrations in the Upper and Lower Hudson River.

4. Provide estimates of PCB body burdens under specific scenarios for use in the human health and ecological risk assessments.

During the first part of the project, MCA reviewed available Phase 1 and Phase 2 data and developed a framework for relating body burdens of PCBs in fish to exposure concentrations in Hudson River water and sediments. This framework is used to understand historical and current relationships as well as to predict fish body burdens for future conditions. Cadmus developed statistical models relating PCB concentrations (on an Aroclor basis) in water and sediments to fish body burdens in the upper and lower Hudson Rivers. MCA developed preliminary probabilistic bioaccumulation models to describe exposure-body burden relationships using a mechanistic approach. These probabilistic food chain models provide information on the fractions of the fish

populations that are at or above particular PCB levels and explicitly incorporate variability inherent in the underlying data to complement the single population statistics provided by the statistical models.

The models are designed to be implemented in one of three forms: as Monte Carlo spreadsheet models, equations combining individual distributions into cumulative distributions, and as nomograph or look-up tables.

Progress to date in accomplishing these objectives is summarized in the Phase 2 Preliminary Model Calibration Report of September, 1996.

2.3 TASKS

2.4 ECOLOGICAL DATA TABULATION, STATISTICS, AND MODELING

2.4.1 Correlation of fish PCB burdens to environmental concentrations in both sediment and water via a bivariate BAF approach.

MCA will continue to provide guidance and internal review of the statistical regression analyses being conducted by Tetra Tech, Inc. This task also involves tabulating values from the literature on relationships for PCBs between water, sediment and fish.

2.4.2 Development of probabilistic bioaccumulation models.

These models are designed to identify the relative contribution of PCBs in Hudson River sediments and water to body burdens of six selected fish species. These species include largemouth bass, yellow perch, white perch, spottail shiner, pumpkinseed, and brown bullhead. Because forage fish (spottail shiner and pumpkinseed) comprise the bulk of the diet for piscivorous fish such as the largemouth bass, these forage fish are evaluated in terms of a *composite* forage fish.

Preliminary models have been developed based on Phase 2 data and data from other agencies (New York State Department of Environmental Conservation, New York State Department of Health, United States Geological Survey, and General Electric). These models incorporate information on the physiological capacity for accumulating PCBs, dietary habits, food sources, general behavior, and trophic level. The bioaccumulation factors between trophic levels are expressed as distributions rather than single point estimates to incorporate the observed variability in the underlying data and uncertainty about feeding preferences. This provides information on the fraction of the fish populations that are at or above particular PCB levels (e.g., 90% of the fish population is expected to be at or below a particular concentration).

The models require validation data sets, which are not available for all fish species. Consequently, a multifaceted approach is being taken. The bivariate statistical model and the probabilistic model represent two approaches; use of a third model, such as the Gobas (1993) gastrointestinal biomagnification model is also being explored.

Water Column to Water Column Invertebrate Component

Results from the preliminary models indicate that the water column to water column invertebrate pathway represents a significant exposure pathway. There are no water column invertebrate data from the Phase 2 data set. Further analysis on this pathway is required and included in this task.

There are a number of alternate approaches presented in the Phase 2 report. These approaches are being explored in greater detail as part of this task.

Role of Direct Water Uptake

Currently, the models implicitly incorporate direct water uptake through the water column to water column invertebrate pathway. Other modeling efforts have shown that dietary exposures are the primary contributors to body burdens. The available literature on the role of water versus food pathways in observed body burdens has been obtained and is being evaluated as part of this task.

Largemouth Bass and Other Piscivorous Fish Models

The model for largemouth bass presented in the PMCR needs to be refined. There are no data available from the Phase 2 data set for largemouth bass of a size suitable for human consumption. Consequently, the bioaccumulation relationship between largemouth bass and its primary food sources rely on data from the New York State Department of Environmental Conservation Phase 1 data. There are additional NYSDEC data available for 1995 through 1997 that were not used in model development. It is anticipated that the HUDTOX model will generate water and sediment exposure concentrations for use with the probabilistic model, which will be validated against these data.

Further analysis needs to be done to incorporate a benthic invertebrate pathway in the largemouth bass model. Some of the data used in the bivariate statistical model may be appropriate for this purpose. The use of these data will be explored.

Various concerns in using the NYSDEC data were elaborated upon in the development of the bivariate statistical model for the PMCR. One concern is changes in quantitation techniques between and among sampling programs, and the other is the appropriate sediment exposure data to be used. There is large uncertainty in sediment concentrations due to the infrequent and spatially variable sediment sampling programs over the historical period.

It is anticipated that the HUDTOX model hindcasting will be useful in defining exposure concentrations for use with the historical NYSDEC data. This will be explored in this task.

Congener Profiles: Exploring NOAA and NYSDEC Analyses

NOAA and NYSDEC (in addition to TAMS) are currently exploring PCB patterns in Hudson River fish by comparing congener patterns over a geographic gradient. The pattern of congener uptake between and among fish species provides important information on the nature of PCB uptake generally. Initial exploration into congener profiles reveals that this approach can provide a clearer

understanding of how fish are exposed to PCBs and the relative importance of sediment versus water pathways. Although congener profiling is not included as part of the bioaccumulation model development effort, ongoing efforts by NOAA and NYSDEC are being evaluated to provide perspective on congener-specific attributes of uptake contributing to the total body burden of fish.

Model Implementation

This task will evaluate the most appropriate means of model implementation. The models are currently designed to take starting sediment and water concentrations in spreadsheet form. The final models may be implemented in three ways: as Monte Carlo spreadsheet models, as equations combining individual distributions into cumulative distributions, and as nomographs or look-up tables. The Monte Carlo spreadsheet models have been developed. Final equations combining individual distributions into cumulative distributions still need to be derived, and the final nomograph or look-up tables created. Each of these methods is designed to be implemented through a spreadsheet program.

Use of Other Modeling Approaches, e.g., Gobas Models

Several different modeling approaches are being evaluated in parallel. The modeling approaches each use existing data differently. Agreement between the expected values from each of the models will provide a degree of validation for each of them. The probabilistic model is specifically designed to provide probability distributions on a body burden basis for fish, while the bivariate and the Gobas models provide central tendency estimates of bioaccumulation under specific exposure conditions.

Based on data availability and to insure that the results from the probabilistic model are consistent with other modeling approaches, use of the Gobas model (1993) is being explored. This model has recently been revised and incorporates both sediment and water column food sources, as well as a Monte-Carlo based uncertainty analysis. This model is based on the fugacity, or chemical potential theory. In this model, biomagnification of organic contaminants is primarily a function of digestion and gastrointestinal absorption.

A time-varying Gobas model is also available. Use of this model will be explored as part of this task. In addition, use of a bioenergetic time-varying bioaccumulation model being developed by Quantitative Environmental Analysis, LLC is being explored as part of this task.

Evaluation of Feeding Preferences

NYSDEC has made fish stomachs from the 1996 fish collection effort for the species of interest available for analysis. These stomachs are being evaluated to assist in refining feeding preferences for each of the species considered in the bioaccumulation models. Stomach contents are being identified down to the lowest level practicable and combined with previously collected data and data from the literature to develop specific feeding preference allocations for the models.

2.4.3 Evaluation of models through yearly hindcasting.

The probabilistic bioaccumulation models are developed by evaluating relationships between particular trophic levels (as represented by specific species) and their food sources (taking into account information on the physiological capacity for accumulating PCBs, dietary habits, food sources, and general behavior). The models need to be validated by "predicting" historically observed levels of PCBs, and/or comparison to data from ongoing field studies (*i.e.*, General Electric, New York State Department of Environmental Conservation, and United States Geological Survey). This hindcasting will be done on an annual basis for each of the years for which data are available and for those species for which data are available.

Note that in the case of the largemouth bass, the historical data set has already been used to develop the model, but data from 1993 through 1997 have been held in reserve for validation purposes. Also, the models would benefit from additional synoptic sampling of sediment, benthic invertebrates, water column, water column invertebrates, and fish, considering the numerous data gaps (*i.e.*, locations where benthic invertebrates were collected but no forage fish, there are no Phase 2 congener water column invertebrate data, there are no data for largemouth bass of a size suitable for consumption, and so on).

2.5 COMBINED DATA INTERPRETATION AND MODELING

2.5.1 Coordination of modeling efforts of Limno-Tech.

Exposure outputs from the LTI models will be used as starting concentrations for the probabilistic models. These exposure outputs are in the form of total PCBs, the sum of tri-and-higher-clorinated PCB homologues, and five individual congeners or coeluting congener groups. Some of these exposure outputs will need to be converted to run the probabilistic models. This is because the probabilistic models will be used for the human health and ecological risk assessments, which require selected Aroclors and total PCB concentrations. Note that the human health risk assessors require a distribution of predicted fish concentrations.

This task requires interaction with other project team members, particularly LTI and Tetra Tech to insure that PCB concentrations are expressed in, or are convertible to, a form that is useful to other aspects of the project.

2.5.2 Estimate body burdens of PCBs under No Action, major flood, and various remedial scenarios.

The HUDTOX model will be used to simulate impacts due to No Action, major flood scenarios, and various remedial scenarios for the Upper Hudson River. PCB water column and sediment concentrations from the No Action and major flood simulations will drive the food chain models (both statistical and probabilistic). The probabilistic models require annual averages on an Aroclor and total PCB basis in support of the human health and ecological risk assessments.

This task will also include conducting up to four predictive model simulations for various remedial scenarios. These scenarios could include evaluation of selected dredging and/or containment scenarios in the upper Hudson River between Fort Edward and the Federal Dam. Design specifications for these scenarios will be determined jointly between project team members.

3. TETRA TECH, INC.

3.1 BACKGROUND

As part of the Phase 2 Further Site Characterization and Analysis of the Hudson River PCB Reassessment RI/FS, The Cadmus Group was selected to provide support for specific aspects of the Phase 2 modeling effort, as well as other activities related to the Reassessment. Cadmus participated in the preparation of the PMCR, and had primary responsibility for Sections 8.4 and 9, which address the bivariate statistical model for fish body burdens.

In October 1996 the remaining scope and budget for the tasks initially assigned to Cadmus were reassigned by TAMS to Tetra Tech, Inc. to retain the services of Dr. Jonathan Butcher, who was Principal Investigator for Cadmus' effort. Tetra Tech has subsequently received additional technical directives from TAMS which are reflected in the revised work plan described below.

3.2 OBJECTIVES

The objectives of the tasks assigned to Tetra Tech in support of the mathematical modeling studies being conducted to support the Hudson River PCB Reassessment RI/FS are the following:

1. Provide a statistical, data-driven methodology for retrospective assessment and prediction of fish PCB body burdens to be used in conjunction with biologically-based methods developed by MCA as part of a weight-of-evidence approach to predicting PCB bioaccumulation in the Hudson River.

2. Develop methods to establish a consistent quantitation basis for historic PCB measurements obtained under a variety of analytical protocols.

3. Provide support to Limno-Tech, Inc. on specific data analysis and interpretation issues.

3.3 PROGRESS TO DATE

The PMCR presents work completed during the first part of the project. For this report, The Cadmus Group, Inc. developed the theoretical framework and provided an initial calibration of the bivariate statistical model relating PCB concentrations in water and sediments to fish body burdens in the Upper and Lower Hudson River. Cadmus also conducted several important data analysis activities, including sediment PCB mass estimates through kriging analysis, estimation of long-term flows and PCB loadings to the Upper Hudson River, determination of PCB phase partitioning relationships, and investigation of relationships among congener groups, total PCBs, and Aroclors in sediments and the water column.

3.4 MODELING TASKS

The following tasks describe the current plan of work being pursued by Tetra Tech in support of the Baseline Modeling effort for the Hudson River PCBs Reassessment RI/FS:

3.4.1 Establishing a Consistent Quantitation Basis for Historical PCB Analyses

Phase 2 data collection for the Hudson River PCBs Reassessment RI/FS provides detailed information on the concentrations of individual PCB congeners in the environment and biota. A wealth of historical data on PCB concentrations is also available, dating back to the early 1970s, and will be used for model hindcasting and the development of empirical relationships between PCBs in the environment and fish body burden. These historical data are generally based on quantitations to Aroclor standards using packed column gas chromatography, which does not represent the full spectrum of PCB congeners identified by Phase 2 capillary column GC/ECD methods. In addition, Aroclor quantitations do not have a consistent meaning across different sampling campaigns, as the results depend on the standards used and the protocol for converting chromatogram peak heights to Aroclor concentration equivalents.

Total PCBs (as the sum of all PCB congeners) are not available in the historic record, because the packed-column GC quantitations miss the monochlorobiphenyls and most or all of the dichlorobiphenyls. The different historical quantitation methods, however, either give or can be converted to an estimate of the sum of tri- through deca-chlorinated congeners, denoted as Tri+. As described in Section 1, model initial conditions, loadings, and calibration targets will be computed for Tri+ for use in the long-term calibration of the HUDTOX model.

For the statistical analysis of fish body burdens, NYSDEC fish quantitations are in terms of Aroclor equivalents, with several method changes over time. These different quantitation methods must also be converted to a consistent basis for application of the statistical methods.

This task addresses the conversion of historical measurements to a consistent basis for use in data analysis and modeling. Evaluation of the interpretation of historic data will be based on documentation of the historic quantitation methodologies coupled with "what if" analyses of Phase 2 congener data. The "what if" analyses consist of numerical experiments to interpret what would be reported if Phase 2 congener data had been analyzed using historic packed-column protocols.

Some work on this task has already been completed in connection with the PMCR, but additional research is necessary to finalize appropriate corrections to a consistent basis of analysis. The major historic data sets to be examined under this task are:

- NYSDEC fish data
- 1976-78 sediment data from the upper Hudson River
- 1984 NYSDEC sediment data from the Thompson Island Pool
- USGS water column data

3.4.2 Partition Coefficients for PCB Model State Variables

For the HUDTOX model calibration, LTI has proposed several PCB state variables:

1. The sum of tri- through deca-chlorinated congeners (Tri+);
2. Total PCBs; and
3. PCB congeners BZ#4, 28, 52, 90+101, and 138 individually.

For each of these state variables, estimates of partition coefficients will be required for the model. Building upon preliminary work presented in the Data Evaluation and Interpretation Report for individual congeners, Tetra Tech will estimate both two- and three-phase partition coefficients to organic carbon for each of the model PCB state variables.

3.4.3 Revision and Recalibration of the Bivariate Statistical Model

The PMCR contains a preliminary application of the bivariate statistical model, based on NYSDEC fish data for 1977 through 1992. For the Baseline Modeling Report, this preliminary application will be revised and recalibrated. Revisions will incorporate comments received on the PMCR and will include additional exploratory data analysis. Additional sources of data which have become available since the PMCR include:

- *NYSDEC 1995 and 1996 Fish Data*: The calibration of the bivariate statistical approach in the PMCR used NYSDEC fish analyses for 1977 through 1992. NYSDEC fish results for 1995 and 1996 have recently been released, and are now incorporated in the database.
- *GE 1990 Fish Analyses*: GE collected approximately 100 fish samples in 1990; however, the initial PCB results were rejected during QA. GE has now reanalyzed sample extracts using NEA capillary column methods and the results have been provided to EPA.
- *NOAA Fish Analyses*: Results predicted by this method will be compared to results of fish samples collected by NOAA in addition to those collected as part of EPA's Phase II sampling effort.
- *Sediment Data*: The analysis presented in the PMCR used simplistic approximations to time trends in surface sediment concentrations, based on examination of High Resolution Coring results and the GE 1991 sediment survey. Recalibration of the model will first incorporate additional evidence on sediment concentrations available from the 1976-78 sediment survey and the Phase 2 Low Resolution Coring effort. Tetra Tech will also investigate use of HUDTOX model predicted surface sediment concentration time trajectories for use in the bivariate statistical model.

In addition, Tetra Tech will work closely with MCA to coordinate interpretation and application of the bivariate statistical model, the Probabilisitic Bioaccumulation Model, and the Gobas model. As part of this effort, Tetra Tech will review and comment on application of the Gobas model and any alternative biologically-based bioaccumulation models proposed by GE.

3.4.4 Combined Geochemical and Ecological Data Interpretation and Modeling.

This subtask represents the integration of the various modeling efforts by the Reassessment team. As part of this effort, Tetra Tech will provide model results and interpretation for the Multivariate BAF approach. In particular, Tetra Tech will use results of sediment compartment hindcasting provided by LTI to analyze and potentially refine the sediment pathway representation in the Multivariate BAF approach. Also as a part of this effort, Tetra Tech will participate in a series of discussions led by TAMS to obtain an overall perspective on the geochemical, ecological and modeling aspects of the Phase 2 program.